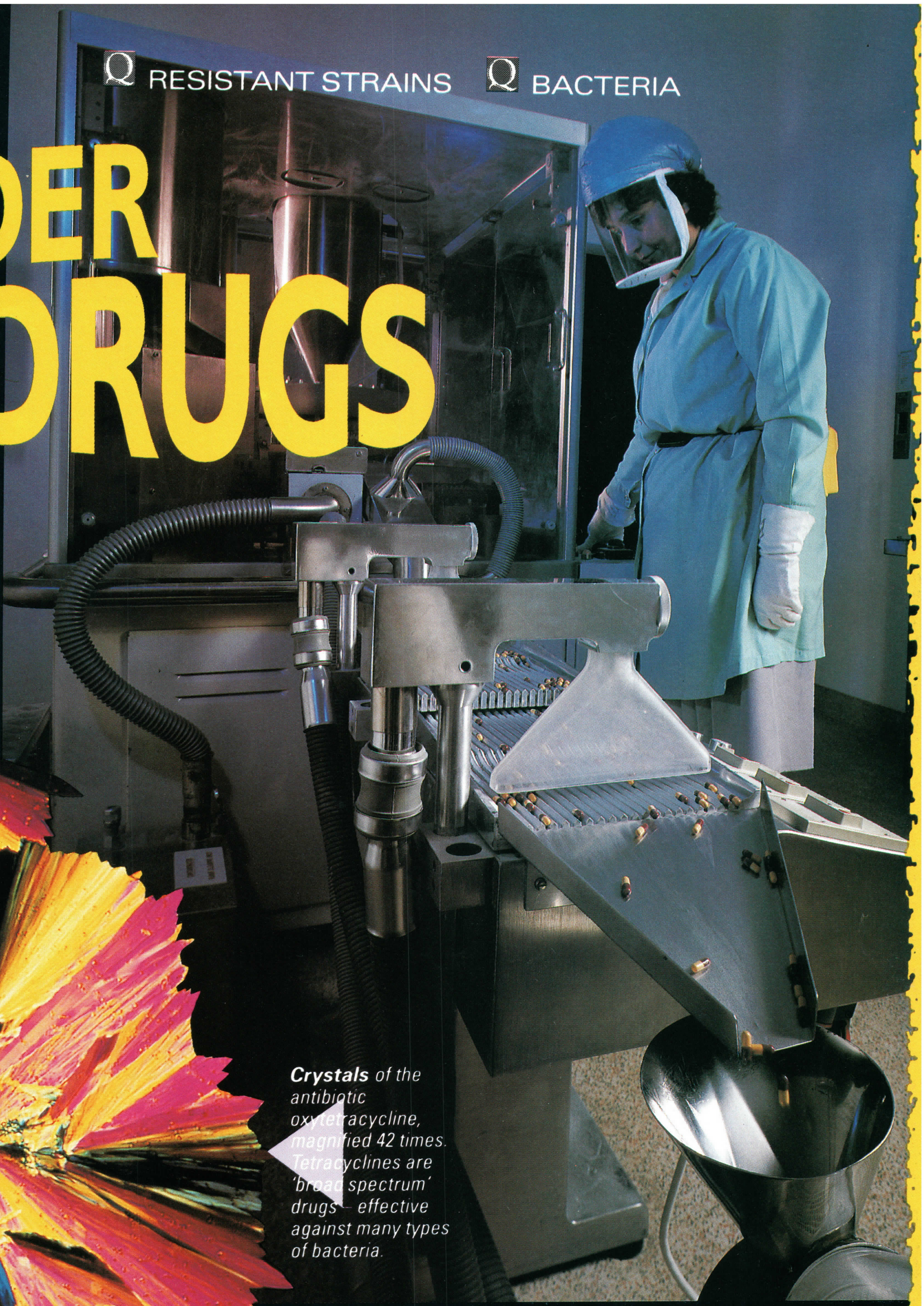
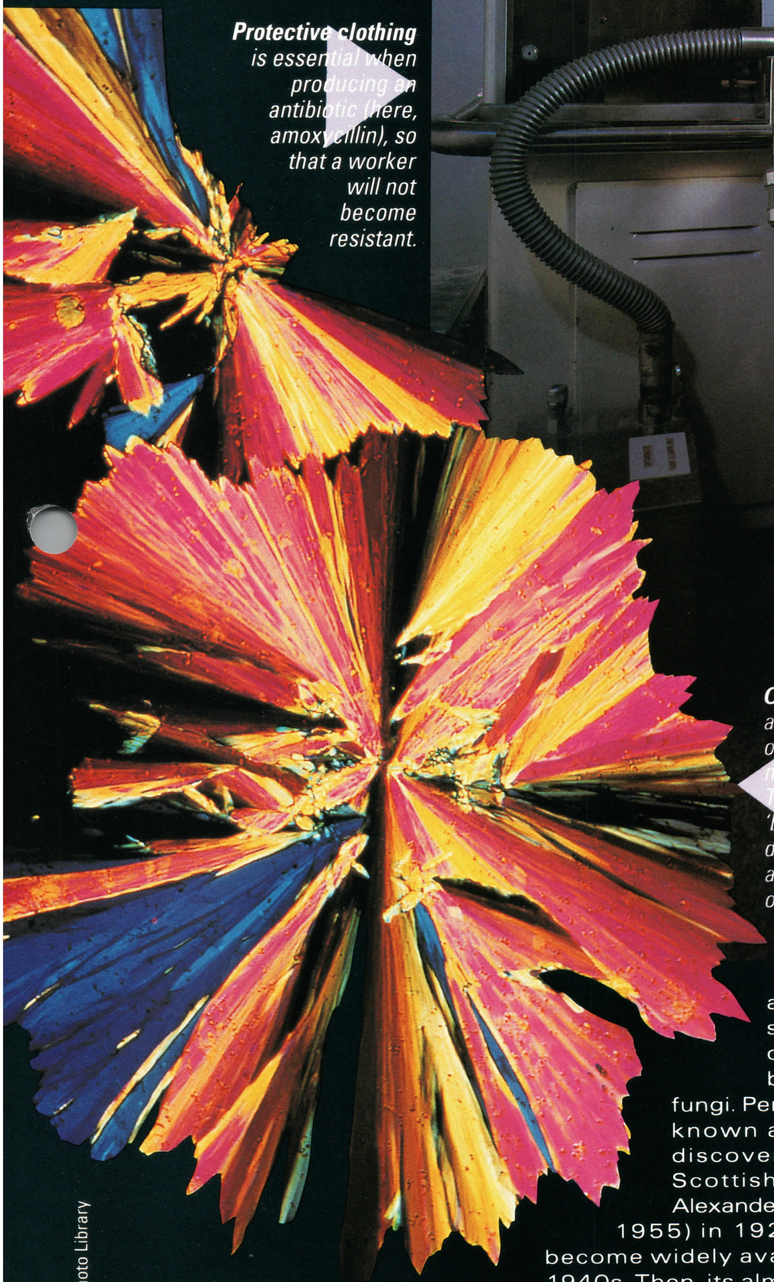
WONDER DRUGS



Protective clothing *is essential when producing an antibiotic (here, amoxycillin), so that a worker will not become resistant.*

SmithKline Beecham



Crystals *of the antibiotic oxytetracycline, magnified 42 times. Tetracyclines are 'broad spectrum' drugs – effective against many types of bacteria.*

Sidney Moulds/Science Photo Library

MODERN MEDICINE HAS A powerful battery of drugs to fight many of the invaders that breach the body's defences. Some of the most effective drugs belong to a group called antibiotics.

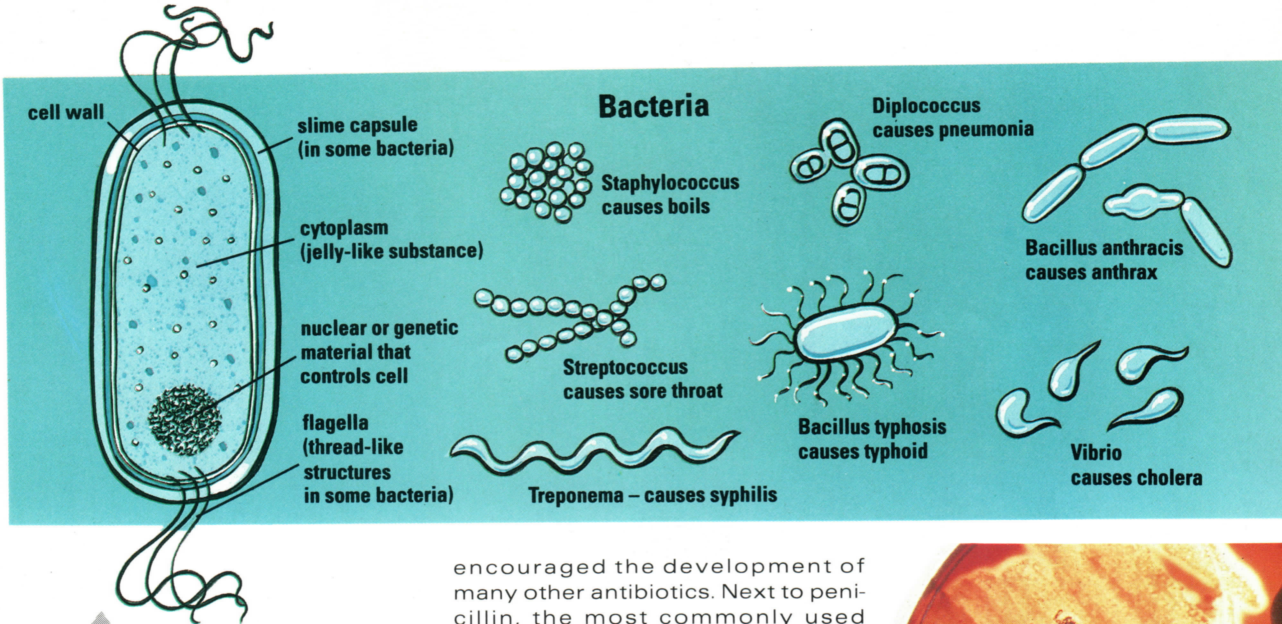
Antibiotics are chemical substances produced by some bacteria and fungi that destroy certain other types of bacteria and fungi. Penicillin, the best-known antibiotic, was discovered by the Scottish scientist Sir Alexander Fleming (1881-1955) in 1928, but did not become widely available until the 1940s. Then, its almost miraculous ability to clear up infection and bacterial diseases made it famous.

Penicillin is a complex chemical produced by the fungus *Penicillium notatum* – a mould that forms on stale bread. When it comes into contact with growing bacteria it prevents them from forming cell walls. (Only plants have cell walls; animal cells are surrounded by thin membranes.) This kills the bacteria, or at least stops them from multiplying further.

Bacteria are primitive, microscopic plants that exist virtually everywhere. Millions of bacteria swarm over each square centimetre of our skin – even after a thorough wash. Billions more live permanently inside us and perform vital functions, such as producing one of the chemicals that help blood to clot.

Invading the body

Disease-causing bacteria, however, can also get into the body, entering through natural openings, such as the nose, mouth, ears and eyes, or via an untreated cut or scratch. Once inside, the bacteria break into living cells and feed on substances in them. As they



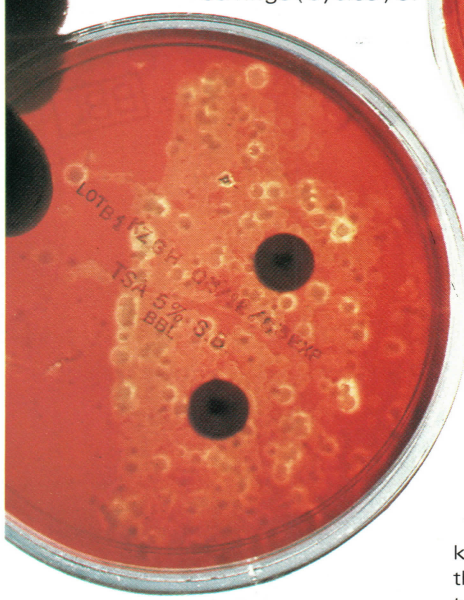
Simon Critchley

***Most bacteria** are found in water, soil or decaying matter; some live in the intestines of animals, including Man. A bacterium is a living organism, from 0.0005 to 0.01 mm long.*

multiply, they may release toxic chemicals that cause fever, vomiting or other symptoms. The body fights back with its own defending army of white blood cells. But this may not be enough to prevent a serious or even life-threatening illness from developing. Then the only hope of a swift cure is a course of antibiotics.

The bacteria that penicillin works best against include those responsible for pneumonia, scarlet fever, meningitis and throat and skin infections. The drug's success has encouraged the development of many other antibiotics. Next to penicillin, the most commonly used antibiotics today are the tetracyclines, which are named after the four (or 'tetra' in Greek) connected rings ('cycles') of carbon atoms in each of its molecules.

When an antibiotic is used, the whole course of treatment prescribed by the doctor must be taken, or bacteria not yet destroyed will stage a 'comeback'. Even after this, there is still the risk that some strains of the target bacteria may become resistant to the antibiotic. These surviving bacteria reproduce rapidly and when the same antibiotic is used against them later it has very little effect. Fortunately, where one antibiotic fails another may still be effective.



***The effect** of the antibiotic biactrin on two species of the Streptococci bacteria that cause sore throats is tested here. Two discs of biactrin in the right-hand dish have inhibited the bacteria's growth. But biactrin has little effect on the strain of bacteria in the other dish.*

Van Bucher/Science Photo Library

Natural and man-made

Many antibiotics, including penicillin, are made naturally by various fungi and bacteria found in soil. Such antibiotics are extracted commercially from bacteria and fungi raised on special, rich nutrients. The antibiotic streptomycin, for instance, is obtained from a certain soil mould. A related fungus has yielded a drug (chloramphenicol) that attacks the bacteria responsible for typhoid fever and salmonella (a kind of food-poisoning). 'Semi-synthetic' antibiotics, such as some of the tetracyclines, have also been developed, by adding chemicals to the growing medium.

SIDE EFFECTS

Many antibiotics have side-effects – that is, unavoidable and unwanted effects. A minor reaction, such as indigestion, is often tolerated; it is more important that the antibiotic tackles a bacterial infection. But if the side-effects are dangerous or an allergy is discovered, the patient is taken off the antibiotic immediately. Reactions to tetracycline, for example, can range from discoloured teeth, as shown below, through blackened finger nails to the skin reddening and blistering when exposed to sunlight.

John Radcliffe Hospital/Science Photo Library

Just amazing!

SPECIAL ADDED EXTRA

BACTERIA MULTIPLY SO FAST THAT A SINGLE BACTERIUM ON YOUR BREAKFAST TOAST COULD BECOME AN ARMY OF 30,000 INSIDE YOUR BODY BY LUNCH-TIME.

Paul Raymonde

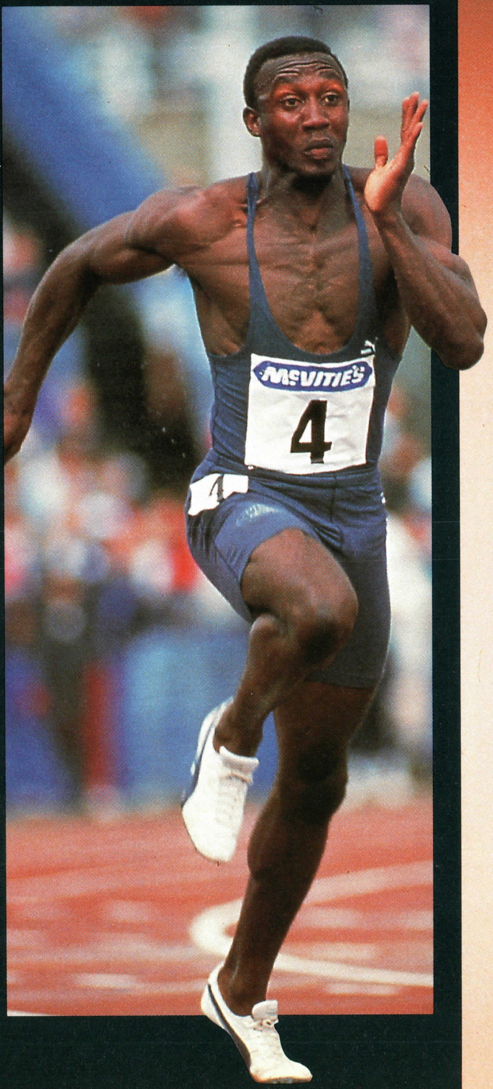
MUSCLE POWER

MUSCULAR TISSUES GIVE our bodies their contours. They attach to the skeleton at specific sites so that when they contract each muscle produces a slightly different movement. The complex result of many muscles contracting in unison produces the controlled precise movements that we all take for granted.

The body has 620 muscles that work to move the 206 bones of the human skeleton. A further 30 or so muscles control the movements of our gut, help us to swallow our food and pass it through the intestines, assist the internal organs and pump blood around the body.

Motor nerve fibres

The muscles that we consciously control are called voluntary muscles. Voluntary muscles can be called striated or striped muscles because of their appearance under the microscope. They are also referred to as skeletal since they are attached to the bones. They are under direct conscious voluntary control from the brain. With very few exceptions (such



Gray Mortimore/Allsport

***Sport** stretches our muscular co-ordination to the limit. Constant monitoring and feedback of information takes place at a phenomenal rate – unknown in the conscious mind. To build a machine with the skills of an athlete would be very difficult.*

***Muscles** make up about 43 per cent of male and 36 per cent of female body weight. Different distributions of muscle and fat equip women better to withstand extremes of environment and give them a longer life expectancy. Men have greater muscular power and speed.*

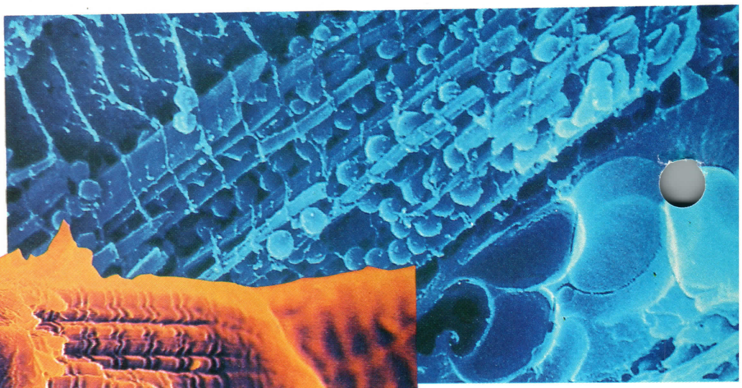
Anthony Crickmay/ London Contemporary Dance Theatre

as the blinking of the eye) single muscles never contract by themselves: rather, sets of muscles contract together or in sequence.

The nervous system is the control mechanism for muscular movement. Signals are sent from the brain and spinal cord along motor nerve fibres. These cause the release of a chemical called acetyl-choline that in turn causes muscle fibres to contract.

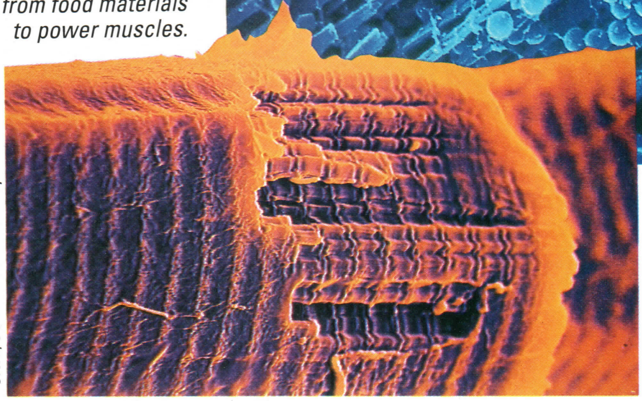
Involuntary muscle

In yet another classification, voluntary muscles are called phasic muscles because they move limbs – as opposed to the supportive, paravertebral muscles of the back, for example, that are constantly contracting to keep the body upright. Involuntary muscles are sometimes called smooth or unstriped because of their appearance under the microscope. Their other name is visceral, since they surround the internal organs or viscera.



Muscle filaments, *in this false colour scanning electron micrograph, are made of proteins. The mitochondria (small balls) process the energy from food materials to power muscles.*

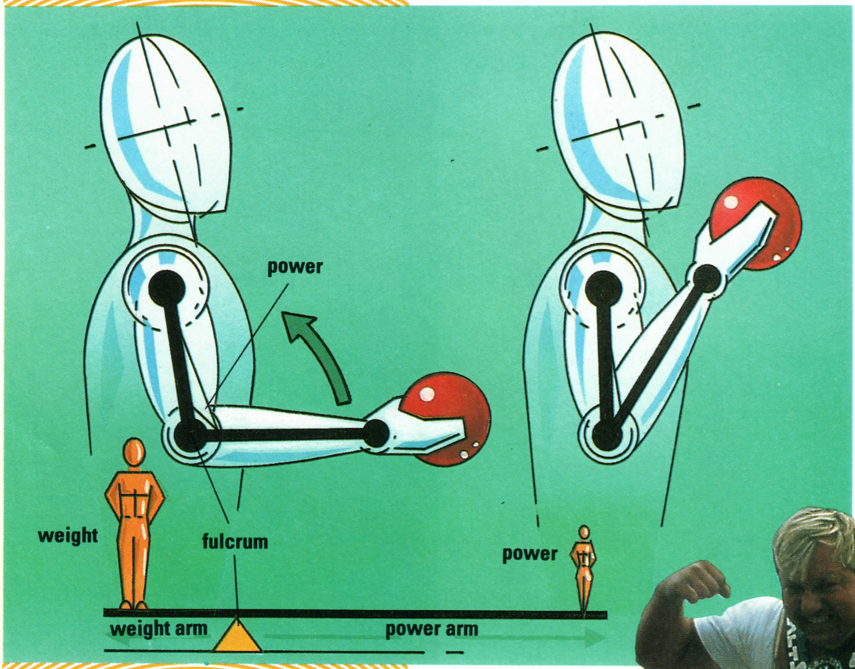
Manfred Kage/Science Photo Library



Striated muscles *are divided into bands of protein filaments that slide over each other to cause contraction of 30 to 40 per cent of their length.*

CNRI/Science Photo Library

LAW OF LEVERAGE



Simon Critchley

Voluntary muscles perform their many functions by pulling on bones and using joints as hinges. The mechanics of levers allow muscles to lift heavy loads by amplifying their power. Pulling the lid off a paint tin with your fingers is almost impossible. But by inserting a screwdriver under the lid and using the edge of the tin as a fulcrum a small force will pop the lid off. The see-saw diagram (above) illustrates the lever effect.

Within the body the spinal column, for example, acts as a fulcrum for the muscles at the back of the neck to pull the head back so that we can look up. The elbow acts as a fulcrum for the arm muscles. In the examples above, the law of leverage can be written: power x power arm = weight x weight arm.

The heart pump

Because there are so many organs all doing different things, the brain could not voluntarily control these and the skeletal muscles at the same time. Therefore, there is a special part of the brain devoted to controlling the muscular activity of internal organs automatically so that the rest of the brain is free to concentrate on voluntary activity of the body (see THE LIVING WORLD page 107).

The heart is a four chambered muscular pump under involuntary control. But because it is a unique type of muscle it has a classification all of its own – 'cardiac'. The biggest difference between cardiac and other types of muscle is the presence, in the heart, of a structure called an

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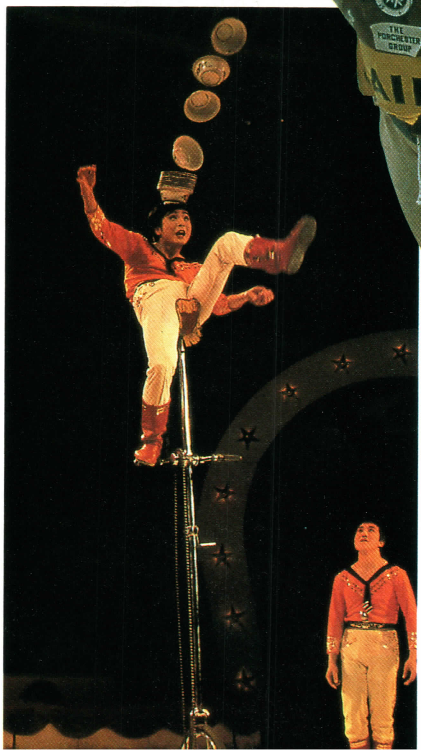
Record-breaking *strongman Dave Gauder pulled Concorde's 102.6 tonnes 12.19 metres across the tarmac at Heathrow Airport, London, in 1987.*



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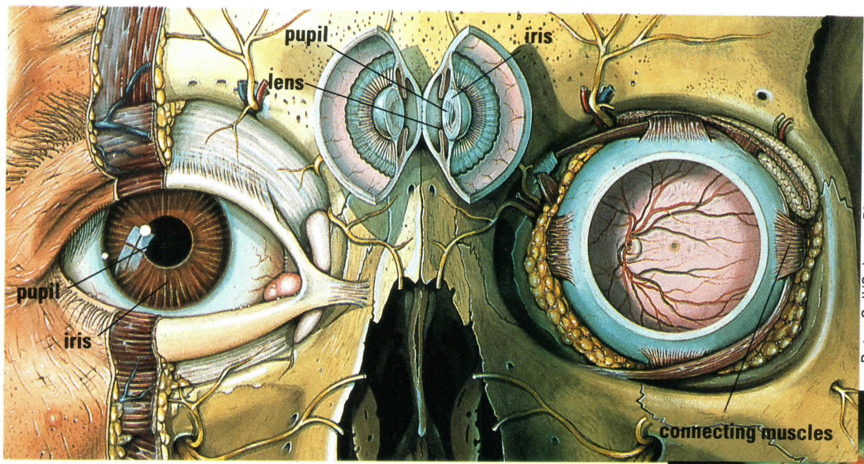
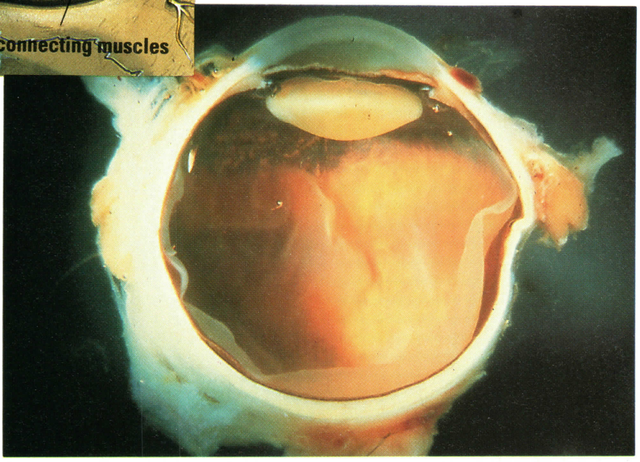
The poise and balance *demonstrated by gymnasts is perfected by the daily training that also builds muscular strength and suppleness.*



Peter Cull/Science Photo Library

ability to contract. The contractile mechanism is very complicated, involving a series of nervous signals and chemical changes. Every muscle fibre is made up of smaller thick and thin fibres called filaments. The thin filaments are made of a chemical called actin and the thick ones of a chemical called myosin.

The myosin filaments provide a number of cross bridges, the ends of which can be chemically attached and detached from the actin filaments. During muscle contraction the two types of filament slide over each other – the cross bridges acting like oars on a boat 'pulling' the filaments over each other.



__The iris__ – above the white oval lens in this eye cross-section – is a ring of muscle that controls the amount of light entering the eye. The eyeball is held in its socket (above) and smoothly rotated by an intricate system of muscles.

Ralph Eagle/Science Photo Library

intercalated disc. This disc of tissue, found between each muscle fibre, helps transmit nerve impulses from one muscle fibre to the next, making the cardiac muscle very efficient.

Contractions

Some muscles with varied functions have developed special characteristics. The muscles that move the eyeball contract and move the eye very quickly (the eye can change its direction of gaze in 1/100th of a second). This type of muscle is termed fast-twitch or white muscle, it looks white due to the lack of a dark substance called myoglobin.

On the other hand, the muscle of, say, the calf does not need to contract at such a fast rate to move the leg, it is termed slow-twitch or red muscle (contracting in about 1/30th of a second). The red appearance is due to high concentrations of myoglobin and the presence of many small blood vessels called capillaries in the muscles.

All muscles have in common the ability to contract.

__Standing still__ for long periods prevents the squeezing action of muscles returning blood through the veins to the heart. This in turn restricts the blood supply to the brain and causes fainting. Guardsmen on duty bend their knees and rise onto their toes to contract their calf muscles, stopping themselves from fainting.

Tony Stone Photo Library, London

Muscle pairs

While one muscle is contracting and becoming shorter, for example the bicep – at the front of the upper arm – the muscle on the back of the upper arm – the tricep – is relaxing and lengthening. Muscles work together in pairs. One moves a part of the body in one direction and the other moves the same part of the body in the other direction. Other muscles act as stabilizers – to make movements both smooth and controlled (see THE LIVING WORLD page 106).

BURNING SUGAR

Working muscles convert fresh supplies of oxygen and glucose (sugar), supplied by the blood, into mechanical work. The chemical process breaks down the glucose into carbon dioxide and water and in doing so releases the energy that muscles use to contract.

During exercise the blood cannot supply oxygen fast enough, and so muscles convert stored glucose (glycogen) into lactic acid without the help of oxygen. Thus exercise is slimming because it uses up the body's stores of sugar.

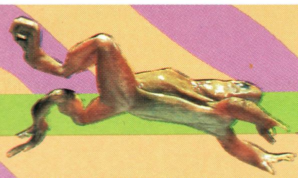
There is a limit to the intensity with which we can exercise our muscles. Beyond this movement becomes painful and then impossible. Lactic acid accumulates, tiring the muscles and causing cramps. This excess is removed by oxygen, which the body brings in rapidly by panting to pay off the oxygen debt.

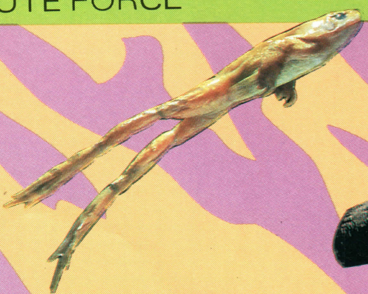
Just amazing!

PEA BRAIN

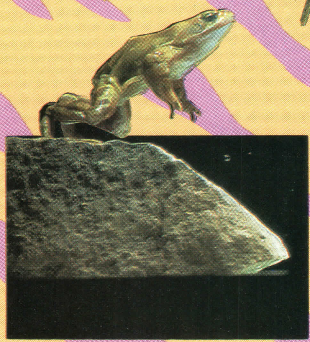
MUSCLES ARE THE HEAVIEST COMPONENT OF THE HUMAN BODY. FOR A MAN OF 70 KG MUSCLES MAKE UP ABOUT 43% OF BODY WEIGHT – WHILE THE BRAIN MAKES UP ONLY 2%.

Paul Raymonde



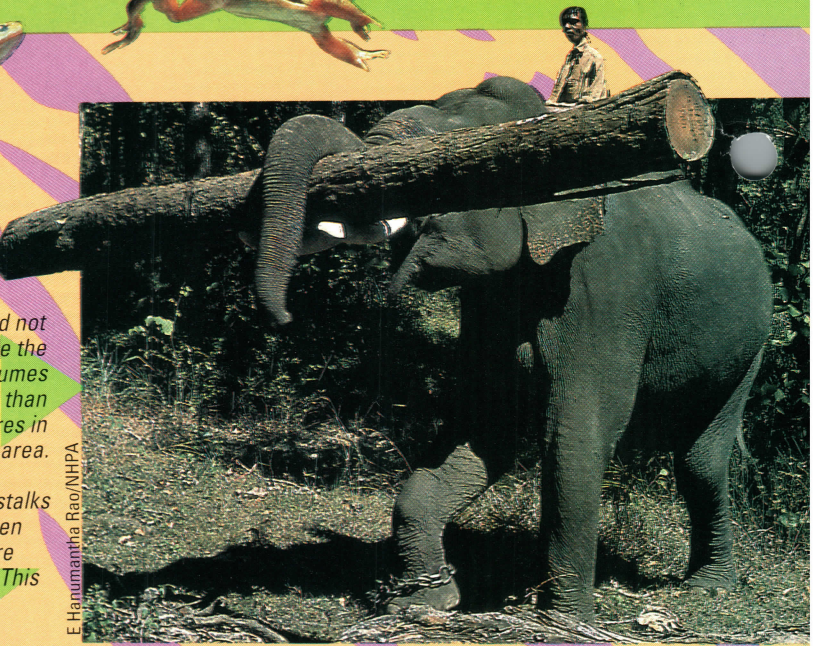


The explosive power *of the frog's hind legs sets it apart from other amphibians. They can propel the frog twelve times its own length.*



Stephen Dalton/NHPA

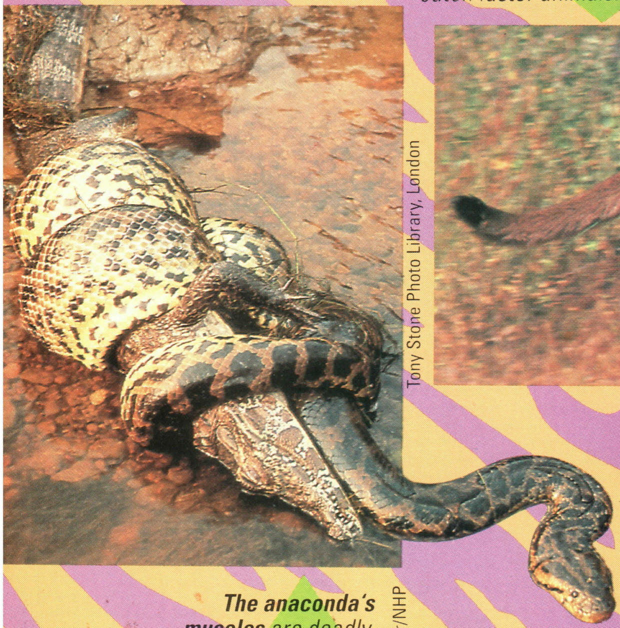
The elephant's size *evolved not for strength, but to enable the species to live on great volumes of less nutritious plants than required by smaller herbivores in a competitive feeding area.*



E Hanumantha Rao/NHPA

The cougar, *like most cats, stalks prey. Powerful hind limbs then provide the thrust for capture with a short burst of speed. This acceleration allows cats to catch faster animals.*

Tony Stone Photo Library, London



Martin Wendler/NHP

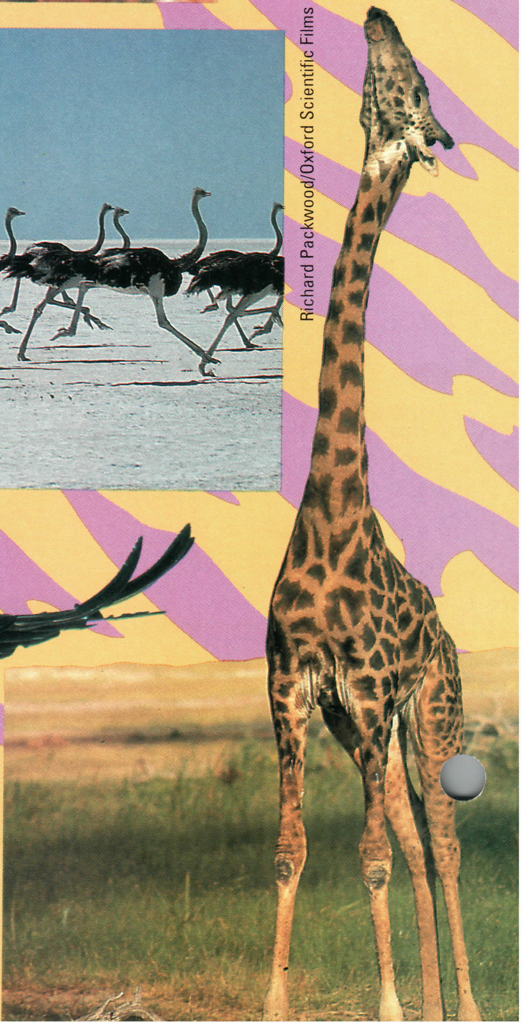
The anaconda's muscles *are deadly. The snake, the largest of boas, kills by constriction. It winds around its victims and contracts its muscles —squeezing prey until it suffocates.*

Jen &Des Bartlett/Bruce Coleman Ltd

The flightless ostrich *– the world's largest living bird – is built for running over the plains of its native Africa. A fully grown male stands 2.5 metres tall.*

Stephen Dalton/NHPA

The powerful legs *and sharp claws of the bald eagle enable it to seize and carry off live prey, such as fish, rodents and even young lambs.*



Richard Packwood/Oxford Scientific Films

The giraffe *has evolved to strip food from tree branches. The result is badly designed – it puts strain on the supporting muscles of the back and the spine.*

HOMESPUN

Spiders construct intricate webs to catch weak flying insects that cannot see fine silk. To start the construction of an orb web, the spider casts a single pilot thread to the wind until the other end is anchored.

MAN IS NOT THE ONLY animal that likes to build. Apart from smaller mammals such as the beaver, there are less sophisticated creatures that engage in construction. Insects, in particular, build for shelter, protection or to trap other animals.

These animals are small. They are more vulnerable to attack and to extreme heat or cold. For example, the larvae of butterflies, moths and caddis fly build themselves cocoons in which they pupate — that is, when they metamorphosize or change from their infant to their adult form.

Unprotected

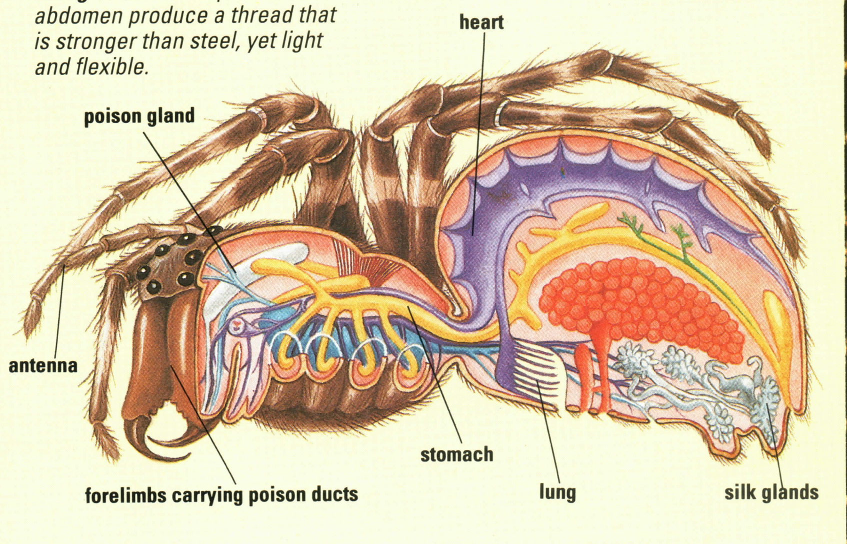
At this stage of their development they are unable to protect themselves by either fight or flight, so they wrap themselves up against the world. They are able to secrete silk or similar substances to spin cocoons around themselves, or to cement together grains of sand, sticks or bits of leaf to form shelters. These are extremely tough and present an impenetrable shield to the larvae's normal predators.

The most famous of the cocoon producers is the silkworm. These are raised on mulberry leaves. The silkworm's cocoon is woven from a single thread between 600 to 900 metres long. A protein called fibroin is secreted in liquid form from two glands in the worm's head. This hardens on contact with the air. A second pair of glands produce a gummy substance called sericin that sticks the turns of the thread together.

The domesticated silkworm makes a completely closed cocoon that would be broken by the emerging moth, so the larva is killed by steam or hot air.

Anatomy of a spider

***Silk glands** in the spider's abdomen produce a thread that is stronger than steel, yet light and flexible.*

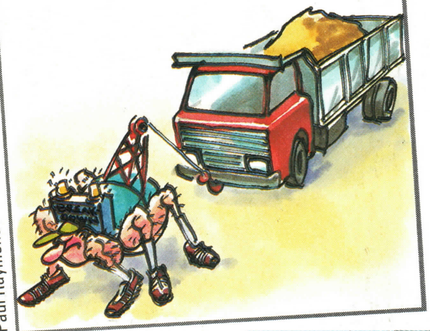


Tony Stone Photo Library, London

Just amazing!

WEBS OF STEEL

THE SILK PRODUCED BY SPIDERS AND INSECTS IS STRONGER THAN THAT OF HIGH GRADE STEEL DRAWN TO THE SAME DIAMETER.



Paul Raymonde

while still inside.

The undomesticated tussah silkworm leaves one end of the cocoon open, sealed only with sericin. This moth breaks the seals and escapes without damaging the silk filament.

Silk threads

The cocoons are collected, the binding sericin is softened and the thread is unwound. The silk filaments from several cocoons are twisted together to make a single silk thread that is thicker and strong enough to weave fabric. Silk containing sericin is called raw silk, though this is often removed with soap and boiling water. 'Spun' silk is made with shorter lengths from broken cocoons.

Other forms of silk are produced naturally by other insects and spiders from special glands in their abdomens. They use their multi-jointed arms and mouths to work it into intricate patterns with meshes so fine that they are practically invisible to the spiders' flying prey.

Catching prey

Silk filaments are incredibly strong and light, which makes them perfect for spinning into spiders' webs. The better-known type is the orb-shaped web used for catching prey, and it is a strange fact of nature that two separate groups of spider spin webs of identical designs, although the way they work is very different.

The *Araeidae* and *Tetragnathidae* families of spiders make webs, up to 60 cm wide, that work by having 'capture' threads covered with small sticky droplets to ensnare prey. The other group of smaller spiders, the *Uloboridae* family, produce dry capture threads, but these are covered with a fuzz of fine threads with loops and barbs to snare prey.

The coot *protects its eggs and its young by building its nesting on vegetation in still water. Although the young quit the nest after a few days, they return to the brooding platform for up to eight weeks.*

Barry Walker/Oxford Scientific Films

The bolas spider

Capturing butterflies or moths is difficult because their bodies are covered with tiny scales that are loosely attached and allow them to get free from a web with the loss of only a few scales that soon grow back.

To overcome this problem, one bolas spider that specializes in capturing moths hangs a single thread from one leg and swings it back and forth, or throws it at the moth.

Communal webs

The strand has very large sticky droplets on it that are too much for the moth to escape from, sticking more than just a few loose scales.

The *Agelena consociata* from Gabon and the *Stegodyphus* from Pakistan construct communal webs. Prey is killed by packs of spiders that hunt together. Other spiders build their webs at dawn then, later, eat their webs to give them the raw materials to weave more the next day.

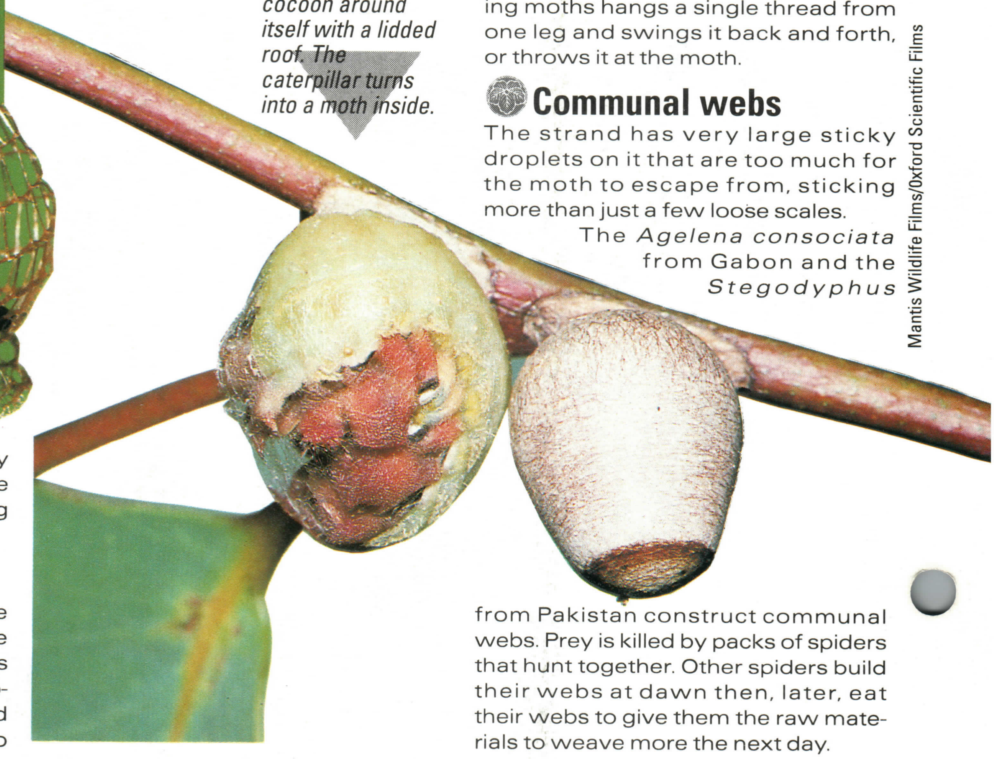
ARTIFICIAL SILK

Man has now been able to recreate the silk from spiders' webs. The US Army's Natick research, development and engineering centre south of Boston has been studying the genetic programme used by the Golden Orb weaver spider, and has managed to reproduce spider silk in the laboratory.

Once the gene responsible for producing silk is isolated, it is transferred to bacteria that produces a soluble version of the silk protein. Then it is refined and spun into a silk-like thread. Researchers hope to adapt the process to produce super-strong fibres, which would have a wide range of uses in military materials that need to be strong and very light, such as bullet-proof clothing or parachutes.

Larvae protect *themselves while they change from the infant stage into adults. This Amazonian moth builds itself a cage.*

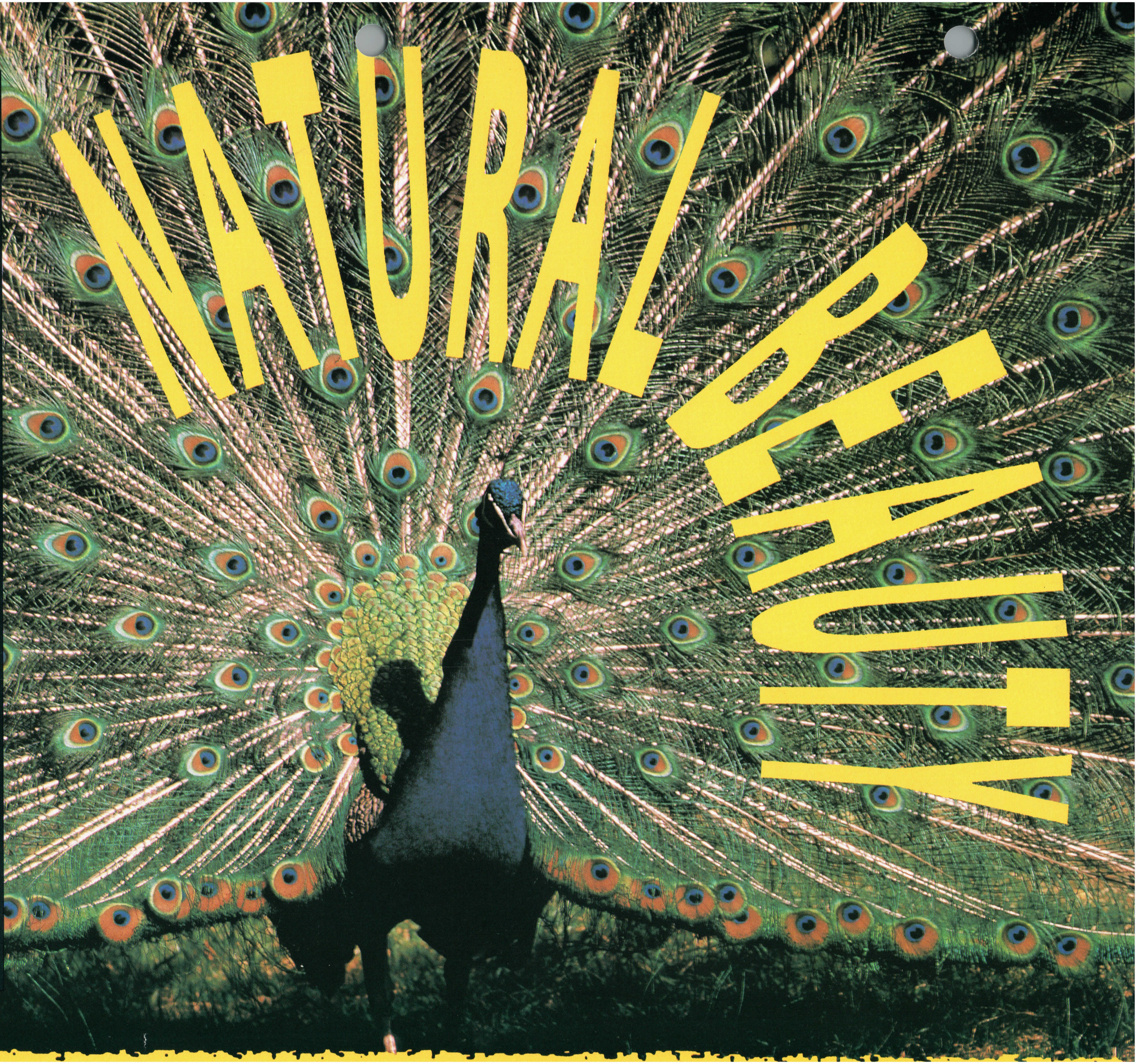
Michael Fogden/Oxford Scientific Films



One cupmoth caterpillar *makes its cocoon next to a finished one. The caterpillar rolls itself up, while it weaves a silken cocoon around itself with a lidded roof. The caterpillar turns into a moth inside.*

Mantis Wildlife Films/Oxford Scientific Films

NATURAL BEAUTY



Tony Stone Photo Library, London

- PEACOCKS
- MATING DISPLAY
- DANGER SIGNALS

MANY ANIMALS AND PLANTS are extremely beautiful. But beauty usually has a purpose. It can help to attract a mate or a pollinating insect, or even warn a potential enemy of danger.

Often the males of a particular species of animal are more colourful or highly ornate than the females. In these species, the female chooses her mate from among the males, which posture or dance at the start of each breeding season. The brighter or more showy the male, the greater are his chances of being selected.

Fantastic shapes

Birds of paradise earn their name from the exotic plumage of the male. While the females are a drab green and brown, the males have brightly coloured, iridescent feathers, which grow into fantastic shapes. The blue bird of paradise, for example, even hangs upside-down, quivering, to display its feathers to maximum effect.

Male peacocks resemble the females when young, but develop fabulous plumes on their upper tail coverts – the feathers that cover the real tail – as they mature. By spreading these special feathers, the male attracts as many partners as possible. After mating he leaves the females to make the nests, incubate the eggs and raise the baby birds alone.

Some birds, while lacking gor-

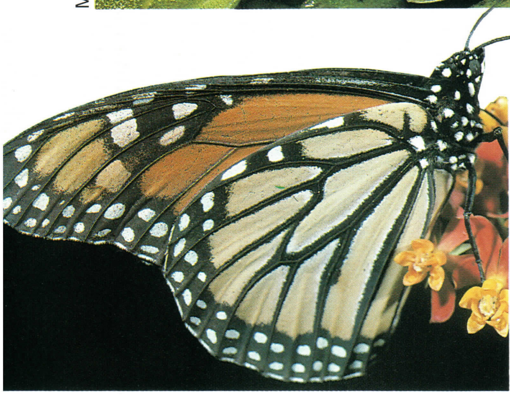
***The male peacock** impresses his mate, the drab-coloured peahen, with a magnificent display of tail feathers and colourful plumage.*

Michael Fogden/Bruce Coleman Ltd

The dart-poison frog, *which inhabits the rainforests of Costa Rica, advertises its toxic qualities with its bright yellow and black skin. In nature, these are warning colours.*

Jane Burton/Bruce Coleman Ltd

The magpie *is known for its thieving. It decorates its nest with bright, often man-made, objects to attract a mate.*



H L Fox/Oxford Scientific Films

A monarch butterfly *feeds on a milkweed flower. Its bold orange and black pattern warns birds and other insect-eating animals that it is poisonous. In autumn, monarch butterflies in North America fly south in large numbers to California and Mexico where they hibernate.*

geous feathers, make up for this by decorating their nests in incredibly ornate ways. Magpies have a reputation for stealing shiny, man-made objects to brighten up their homes.

Blue bowers

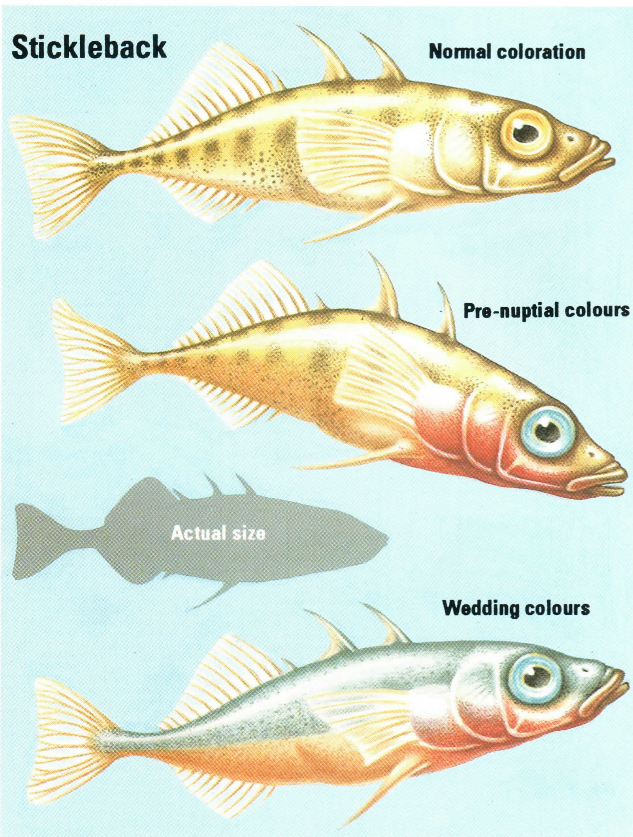
The bowerbirds of New Guinea and Australia go to even more amazing lengths. The male bowerbird builds a special place, not as a nest, but as a mating site. Some species construct neat passageways of grass and twigs, while others erect stick palaces three metres high. Then the bowerbird starts to collect a bewildering range of coloured objects. Blue is a favourite colour – blue pieces of plastic, buttons, pen cartridge cases, bottle tops and so on. Bowerbirds have even been known to kill small blue birds and strip them of their feathers for use as decoration.

Male bowerbirds go to this trouble to attract a mate. Dominant males are able to build bigger and more spectacular collections of objects by raiding, and even destroying, the bowers of their rivals. The females are drawn to the 'wealthiest' males.

Warning signal

Often beauty, or at least gaudiness, acts as a warning signal. Otherwise defenceless creatures, such as caterpillars, use two main methods to avoid being eaten. They either try to blend in with their background so they are hard to spot, or they are purposefully showy to advertise the fact that they would not make a good meal. Brightly coloured caterpillars are generally unpleasant or actually poisonous for predators to eat.

The dart-poison frogs, which inhabit the rain forests of South America, signal an even more deadly



Mark Iley

The male stickleback *is usually a neutral colour (top) that blends in with the background. Before mating though, its body reddens (middle) to make the fish conspicuous as it stakes out a territory. When ready to mate, it becomes even more colourful with a blue back to attract a mate.*

Just amazing!

THE HEAVY BUNCH

THE PLANT WITH THE BIGGEST FLOWER IS THE SO-CALLED 'STINKING CORPSE' LILY FROM SOUTH-EAST ASIA. IT GROWS UP TO 91 CM ACROSS AND WEIGHS 7 KG.

Paul Raymonde

threat with their brilliant colours. The skin of these small amphibians secretes toxins so powerful that the local Indians use the frogs' poison to tip their blowgun darts.

Instant death

Most dangerous of all is the so-called batrachotoxin obtained from the golden-dart poison frog. Merely touching the back of this five-centimetre-long animal, then putting your finger in your mouth would be enough to cause instant death. The average adult golden-dart poison frog contains just 1 mg of venom, but that is enough to kill 2,200 people.

Being colourful is only useful if the creatures you are trying to warn off have colour vision. Nocturnal animals, or those which burrow in the ground or live in the deep sea, almost certainly see only in black and white. But some daytime insects and all daytime birds can see in colour.

Distasteful

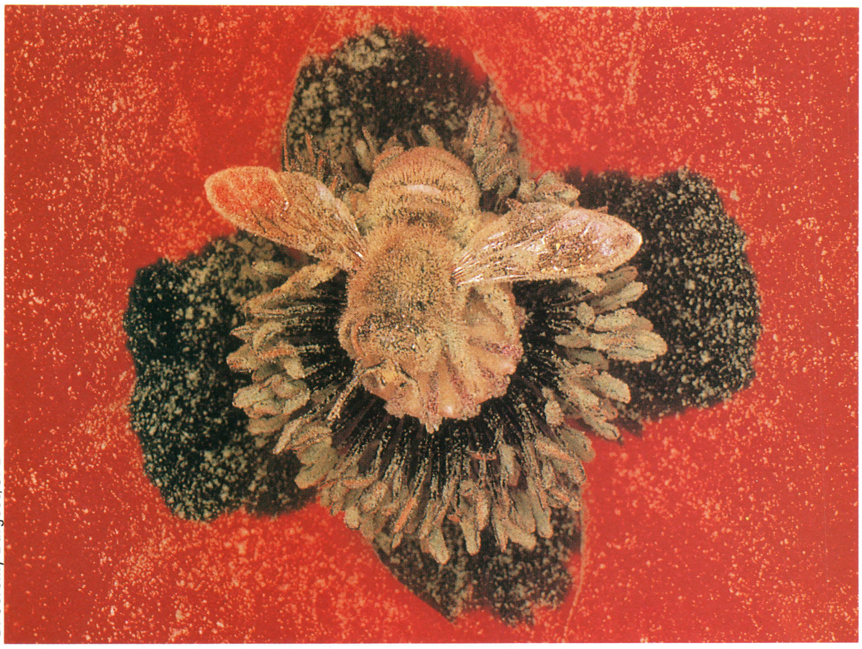
This explains the bright black, orange, and yellow coloration of certain heliconid butterflies that taste horrible to their main predator – birds. One peck and the bird instantly drops its distasteful meal. Being surprisingly tough, the butterfly usually survives the attack and the bird quickly learns the warning colours of the foul-tasting insect and avoids it in future.

Hans Reinhard/Bruce Coleman Ltd

***The bird of paradise** has colourful plumage, especially around the tail, to help it attract a mate in the poor light of the rainforests of New Guinea.*

***The tiger lily** has a spotted pattern on its petals to attract bees and other insects towards its nectar and its pollen.*

L Rue/Bruce Coleman Ltd



Dr Jeremy Burgess/SPL

***Bees are attracted** by flowers. They crawl inside in search of nectar. The anthers – male parts – desposit pollen on its back (right) and the stigma – female parts – pick up pollen brought from other plants.*

Flowers may be pretty to look at, but they have not evolved just to adorn our gardens and hedgerows. The real purpose of flowers is to attract and provide a landing pad for pollinating insects.

Colour preferences

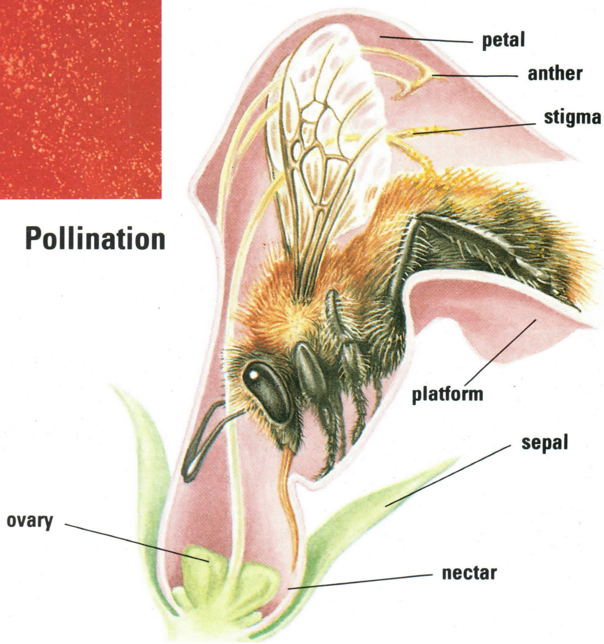
Different insects are drawn to different-coloured flowers. Bright coloured red, orange, or pink blossoms tend to draw butterflies, while pale, scented flowers attract moths in the dark.

The appearance of a flower to a flying insect, however, may be very different from what human eyes see. Bees, for example, have vision that extends to shorter wavelengths than ours so that they can see the ultraviolet reflected by many flowers.

Pollination

As an insect feeds on the sweet nectar secreted by the flower its body brushes against the pollen on the male parts of the plant, known as the stamens. During the insect's visit to the next flower, some of this pollen rubs off against the female part, or stigmas, resulting in pollination.

Pollination



Mark Iley

R Kolar/Animals Animals/OSF

The caterpillar *of the spicebush swallowtail butterfly has fake eyes to frighten predators.*

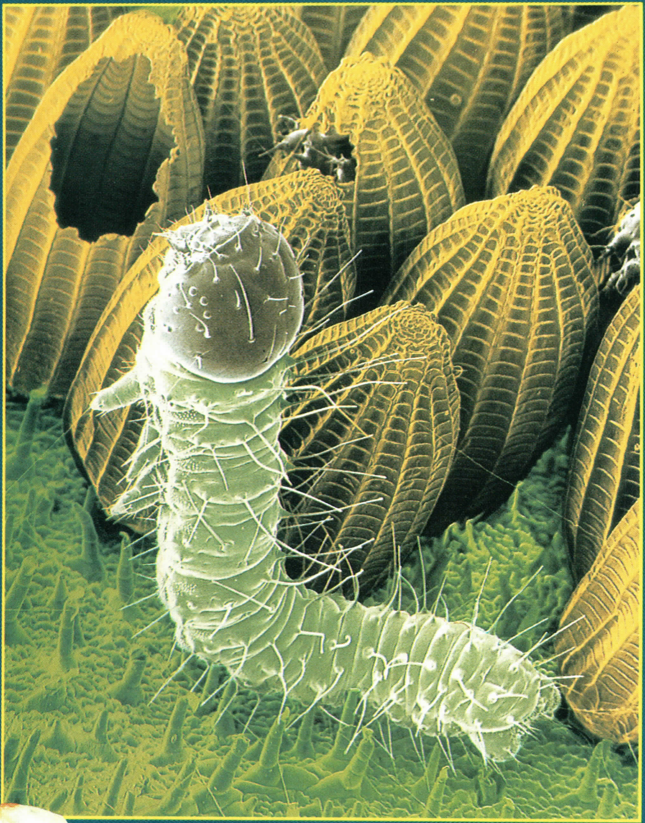
The larvae *of the Japanese oak moth are cultivated not for their looks but for their 'wild' silk.*

Beautiful but destructive, *the caterpillar of the cabbage white butterfly can consume a plant.*

Dr Jeremy Burgess/SPL

The vivid red colour *of this caterpillar from Costa Rica, South America, warns any bird that wants to eat it that it won't make a good meal. It is covered with irritant hairs.*

P Ward/Bruce Coleman Ltd



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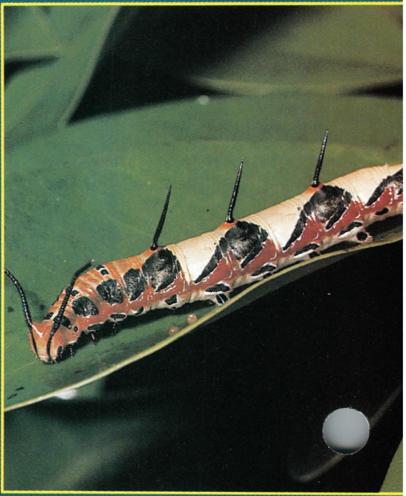


M P L Fogden/Bruce Coleman Ltd

The bright pattern *on the body of this rainforest caterpillar from tropical Mexico draws attention to the spikes on its back.*

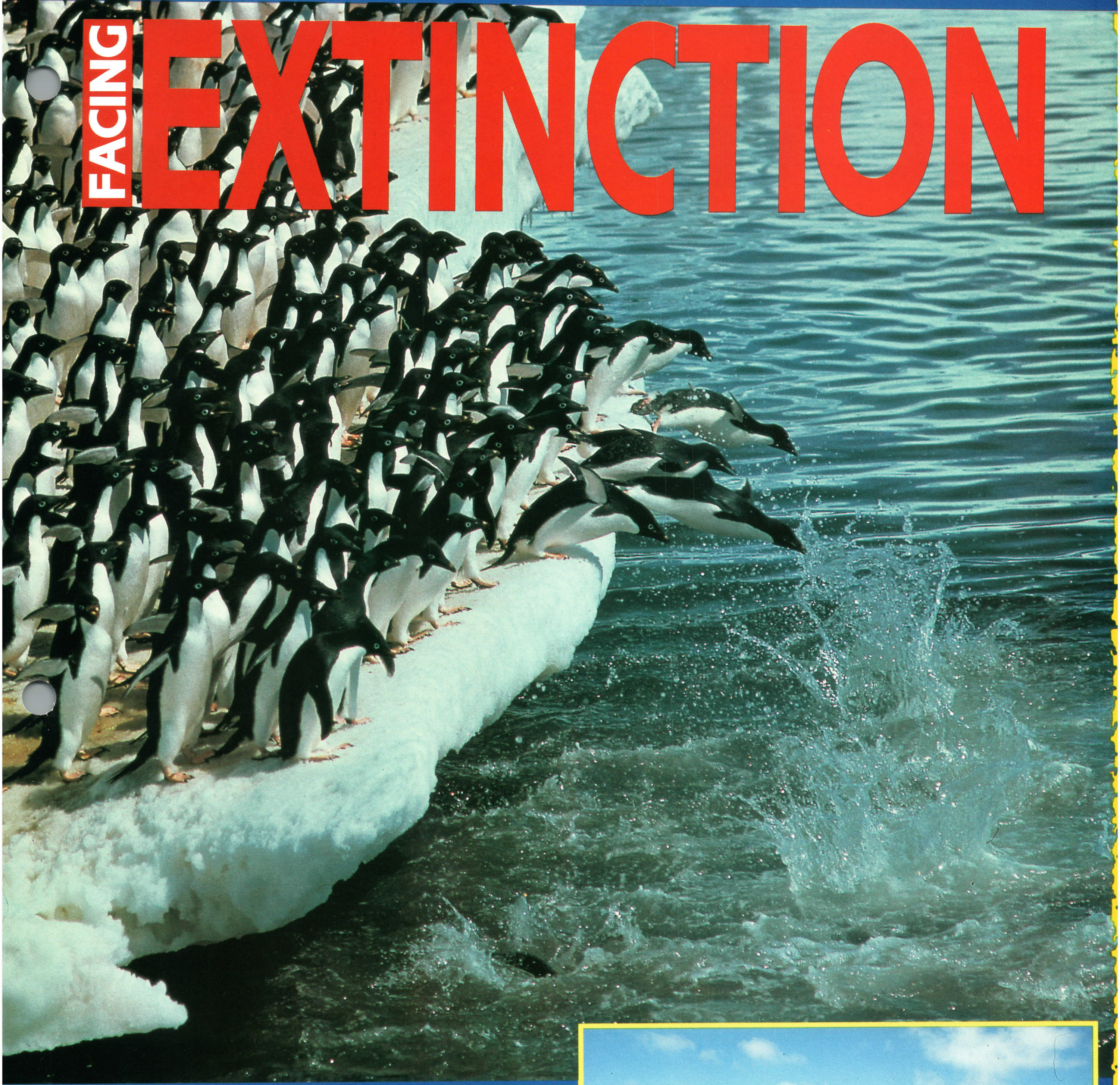
The silkmoth caterpillar *from Costa Rica uses its natural beauty, not to warn would-be predators, but to hide itself from predatory birds and other small forest animals.*

Caterpillars *or larvae do not restrict their natural beauty to the colours and patterns on their heads and bodies. Some are also incredibly graceful in their movements. These two seem to perform an exotic dance as they eat their way along the edge of a leaf.*

J L G Grande/Bruce Coleman Ltd

Carol Hughes/Bruce Coleman Ltd

FACING EXTINCTION



Tony Stone Photo Library, London

ONE OF THE WORLD'S PRETTIEST monkeys, the blind dolphin that inhabits China's Yangtse River and a palm much used by the Ancient Egyptians are among the species most in danger of becoming extinct.

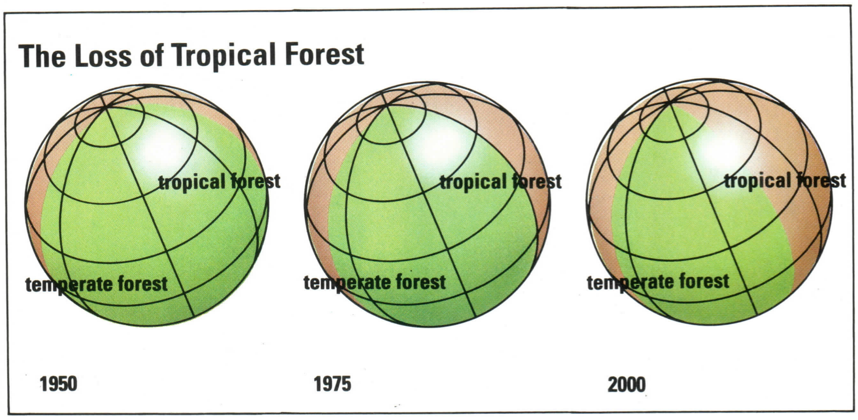
Most endangered species are under threat because of one thing – human activity. Sometimes this takes the form of hunting and trapping, but mainly it is because the demands of human civilization or agriculture are overtaking their habitat.

The endangered monkey is the little black tamarin which lives in the wild in only two small patches of forest in the State of São Paulo in

Adelie penguins *in Antartica. The fragile marine ecosystem of the area is endangered by the threat of mining and oil drilling.*

St. Kilda, *the Western Isles, Scotland, supports large populations of puffins and gannets and is designated a World Heritage Site.*

Peter Gathercole/Oxford Scientific Films



Trevor Hill

Wildlife's natural habitat *is under pressure. The globes show the loss of tropical forest between 1950 and 2000.*

Brazil. It is the rarest and most endangered of the New World monkeys, just 100 remain in the wild.

The black tamarin once occupied a large part of the State of São Paulo. But this was one of the first parts of Brazil to be colonized. What was once lush jungle has now been cut down, leaving just a few widely separated tracts of natural forest.

Conservation

Two small groups now live in the Morro do Diabo and Caitetus reserves. In a conservation effort 25 are being kept at the Rio de Janeiro Primate Centre which contains some of the largest tracts of forest left in the State of Rio de Janeiro.

The baiji dolphin is one of the five species of river dolphins, all of which have very poor eyesight. They don't need acute vision in the muddy waters of the fast-running rivers that they live in. Their other senses though are highly developed and these are used to navigate and find food.

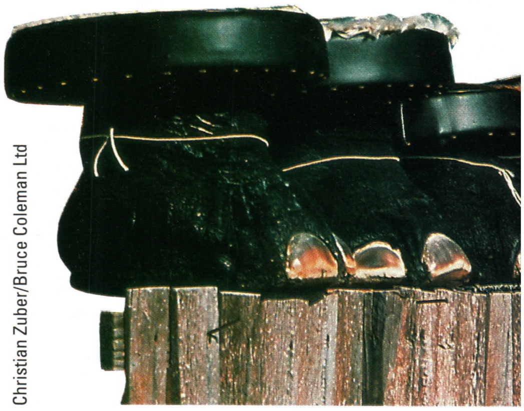
In China's Yangtse River, there are probably less than 400 baiji dolphins left. They are threatened both by fishing and by growing river traffic. The Chinese government is making an effort to save the species by setting aside a special reserve where fishing and boat traffic will be restricted.

It may already be too late for the argun palm though. Scientists are not even sure if there are any of them left – they were depicted in Ancient Egyptian art and the leaves have traditionally been used to make mats.

Sharks in the waters around the Galapagos Islands were indiscriminately killed, just for their fins which were hacked off for use in exotic dishes including shark fin soup. This was discovered when thousands of shark's carcasses were washed up on nearby beaches. 40,000 sharks were said to be killed this way in 1989.

More than 6,000 species of mammals, birds, reptiles, amphibians, fish, insects and invertebrates are listed as being in danger. An additional 578 are considered vulnerable if present trends continue. Also around 25,000 species of flowering plants are considered to be under threat.

Elephant's feet *made into stools – a less common example of the exploitation that threatens the elephant's survival.*



Christian Zuber/Bruce Coleman Ltd

ZEFA

Tropical fish farming *in Florida, USA. Intensive fish farming can have serious consequences for other marine life – seabirds and mammals – as their natural food source is depleted. Salmon farming in Scotland, for example, deprives seabirds of sandeels that are used for fish meal for salmon feed.*

Rare sighting

But all, however, is not gloom and doom. The ivory-billed woodpecker, which was believed to be extinct in the southeast of the US, has been discovered living in Cuba. The purple-plumed bird was forced out of the swampy forests of the lower Mississippi, the large river swamps of the Mississippi Delta, and the cypress swamps of Florida by logging and the removal of the virgin trees they depended on. In the Suwannee River region of Florida, a collector seems to have been responsible for wiping out the remaining population.

The Cuban ivorybill was also under threat by the clearance of forest for sugar plantations. But a recent expedition saw the half-metre long woodpecker eight times in the highlands of eastern Cuba in April 1990. The Cuban government have promised to take action to conserve the ivorybill's remaining habitat.

Just amazing!

DISAPPEARING HEDGES

SINCE 1947, APPROXIMATELY 306,000 KM OF HEDGES HAVE BEEN DESTROYED IN BRITAIN ALONE – ENOUGH TO SPAN THE EARTH FOUR TIMES OVER.

Paul Raymonde

A golden lion tamarin, *one of the species threatened by the destruction of the South American forests, whose trees are its natural habitat.*

RA Mittermeier/WWF

NATURE FIGHTS BACK

WS Paton/Bruce Coleman Ltd

Eric Crichton/Bruce Coleman Ltd

HUMAN INDUSTRY IS AN environmental vandal. But wildlife is more resilient than it is given credit for. Many species thrive on human waste and have taken advantage of the new habitats that industry has provided.

Britain was the country that began the industrial revolution although very few species have become extinct in Britain as a direct result. More habitats have been destroyed by humans through industrialisation cutting down woodlands and hedgerows, by the building of houses and roads and railways and canals.

__Ospreys__ in the Everglades National Park in Florida have found the perfect nesting site – the jib of a derelict crane.

__Poppies__ can still take over a wheat field. Despite modern weed killers, many plants become resistant.

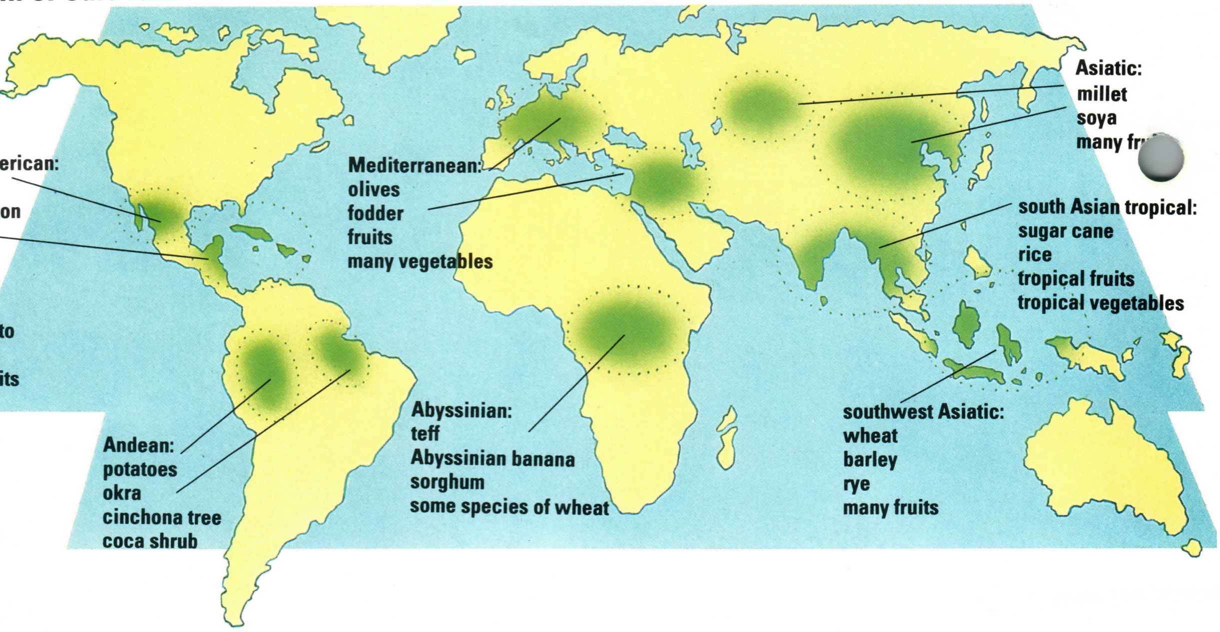
Wildlife moves back

But wildlife quickly exploited the edges of motorways, for example. And when industry has moved on, abandoning old factories and mines, wildlife quickly moves back. Kestrels raise their young in crumbled factory buildings. Jackdaws nest in disused furnaces and old chimneys. Badgers have taken over underground cellars and tunnels to use as their sets.

Once an industrial site has become disused, plants quickly take over. Weeds particularly can grow in any crack or exploit any dirt or puddle. They thrive on poor soil and their roots can crack concrete. And as they grow they enrich the soil, preparing it for other plants to follow.

Orchids often thrive in disused limestone quarries. Mountain mosses quickly colonize old coal mines. Moulds and fungi grow in damp corners or on any decaying waste

Centres of Origin of Cultivated Plants



Cultivated plants *originated from seven areas. The wild cousins of these varieties are found there and can be used to improve the strain.*

material. Trees, also, can grow in foundry slack. Birch, willow and, later, oak trees all manage to thrive in industrial wastelands.

Once vegetation has covered the ruins, animal life soon follows. Insects are the first to return. Many species of ants and beetles can thrive even in the most meagre of habitats – living exclusively on rotting wood, dead leaves and other decaying organic matter.

Polecats

Bees, wasps and butterflies are attracted by the flowers, and birds, especially woodpeckers, are quick to follow. Rabbits move in to graze on the new vegetation. And polecats – the wild ancestors of domestic ferrets – move in to prey on them. This is all the more remarkable as a century ago, polecats were on the verge of extinction. They had been ruthlessly exterminated by gamekeepers who saw them as a threat to young partridges and pheasants. Pheasants themselves were brought to Britain from central eastern Asia.

Reclaimed industrial sites are also a haven for badgers, which had been persecuted by farmers who thought they spread tuberculosis to cattle.

Wild boar

Not all the species that return to these former industrial areas are the natural species that lived there before the factories, quarries and mines were built. In England, for example, wolves, bears and wild boar were extinct long before the industrial revolution. In some areas of Europe – notably Portugal – wolves are making something of a comeback though.

The number of native red deer that used to inhabit England has dwindled to the point where they cannot recolonize. Roe deer that were extinct in England in 1800 have been reintroduced. But the fallow deer which were introduced to England from France by the Normans and muntjac deer from India and China have escaped from parklands and now live wild in woodlands in England.

Edible dormice

Tasmanian wallabies have also escaped from zoos in England and are living wild, as is the edible dormouse. Raised to be eaten in Roman times, it was brought to England in 1902.

Foxes feed on rabbits on old industrial sites, but they have long since accommodated themselves to the ways of man. While they were being killed off in the country, they were making their way up railway lines into the cities where they gorged themselves on the contents of dustbins.

Motorways have produced another new habitat for wildlife. Mink that escaped from farms – where they were reared to make into coats – have used the broad verges to spread themselves across Britain.

Michael Leach/NHPA

Motorways *with their towering concrete bridges make a good habitat for the kestrel. It can swoop down on the shrews and mice that inhabit the verges.*

Andrew Shaw

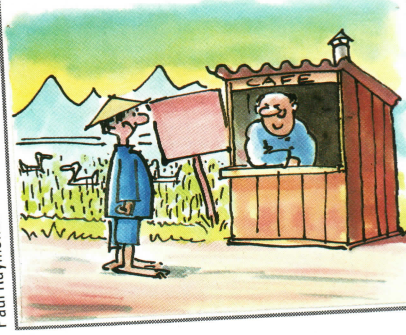
Oil seed rape *is self-seeding and quickly spreads outside the fields where it is cultivated by farmers, taking over the hedgerows from indigenous flowers.*

Stuart [illegible]b/Oxford Scientific Films

Just amazing!

DUCKS TO WATER

CHINA'S BIG SAND COMMUNE USES 220,000 DUCKS TO CONTROL INSECT PESTS IN PADDIES OF YOUNG RICE-REDUCING THEIR NEED FOR CHEMICAL INSECTICIDES BY A FACTOR OF TEN.



Paul Raymonde

DIGESTION

FOOD AS FUEL

MUSCLE POWER

FUELLING THE BODY

Bob Martin/Allsport

A gymnast's muscles *are powered by contractions, which are caused by contractile proteins called myofibrils that run along the length of striated muscle fibre (far right). The proteins use energy derived from the breakdown of glucose to carbon dioxide and water.*

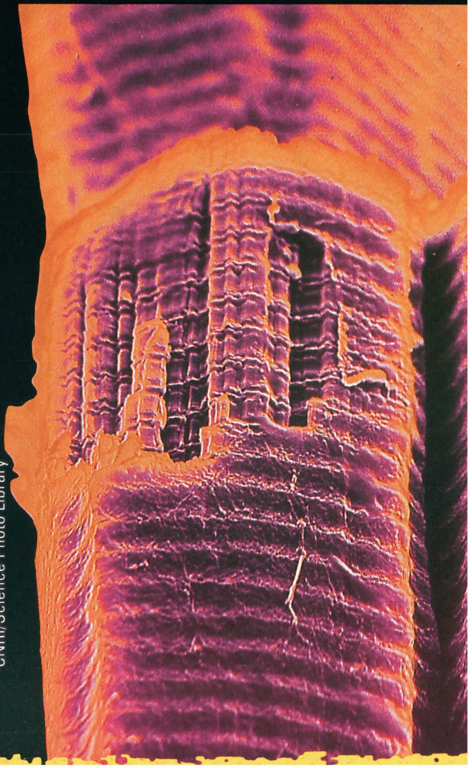
THE ENERGY WE NEED TO move and live comes from the food we eat. But swallowing a mouthful of hamburger or apple is only the beginning of the amazing process of digestion.

Ahead of the food lies a journey lasting about 24 hours through a maze of soft tubes and chambers more than eight metres in length.

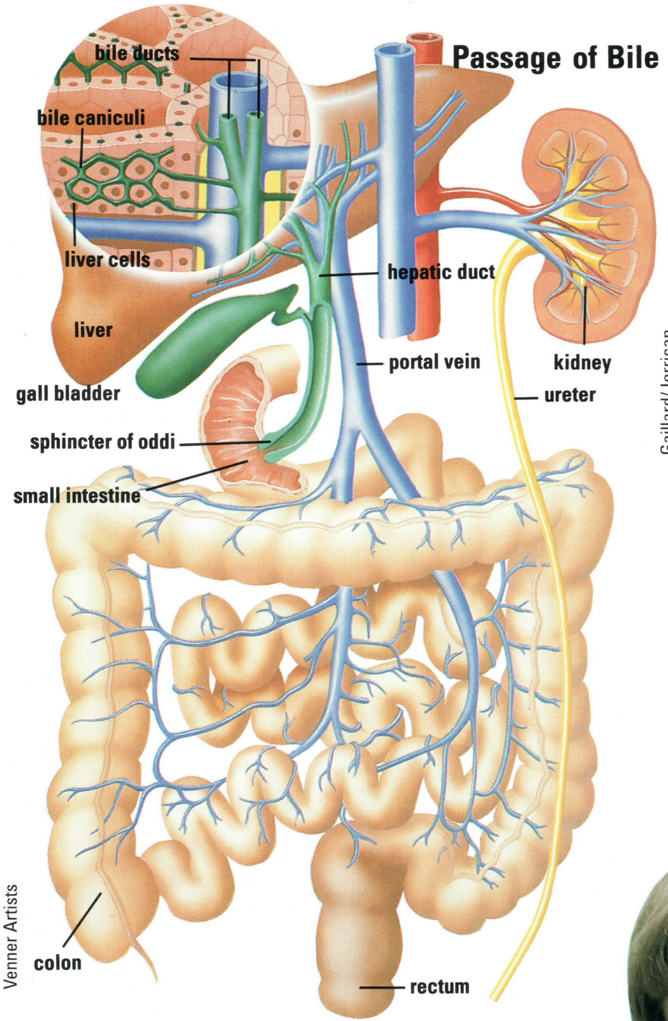
Salivation

Digestion begins in the mouth as the teeth chop up the food into smaller bits and saliva pours in from special glands under the jaws, in front of the ears, and under the tongue. Saliva contains an enzyme – a type of protein – that begins to break the food down and moistens it, so making it easier to swallow.

Within seconds, a soggy ball of food is on its way down the oesophagus, a muscular pipe that passes down the throat and into the



CNRI/Science Photo Library




Gaillard/Jerrican

In the human ***digestive system*** *(far left) a litre of bile per day is produced by the liver and released from the small intestine to break down the fats in food. An electron micrograph of the small intestine (left) shows the villi, through which nutrients are absorbed into the bloodstream.*

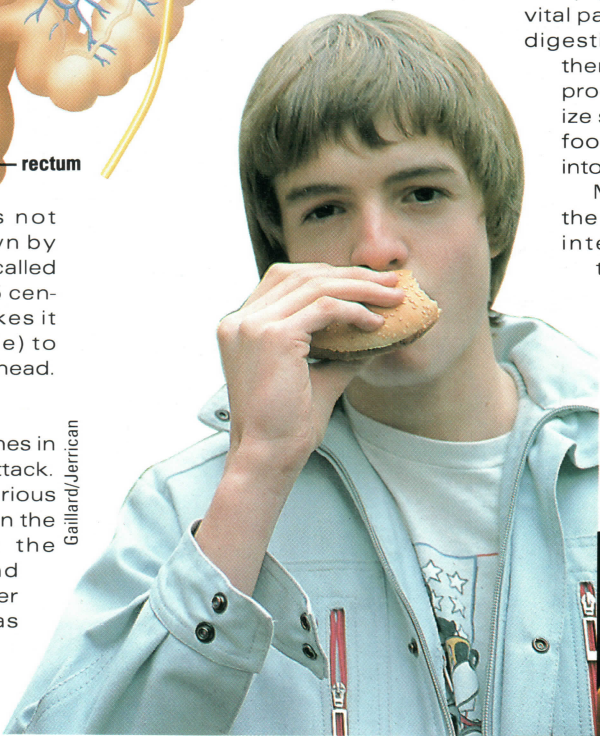
stomach. But the food does not simply drop. It is pushed down by waves of muscular contraction called peristalsis, travelling at about 5 centimetres per second. This makes it possible (though not sensible) to swallow while standing on your head.

Acid attack

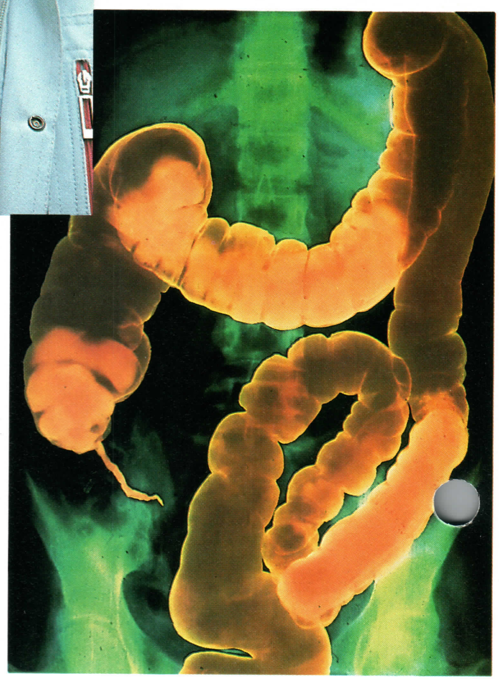
Inside the stomach, the food comes in contact with a fresh chemical attack. Hydrochloric acid, laced with various digestive enzymes, rain down on the meal while the muscles in the stomach wall slowly churn and thoroughly mix the contents. After about two hours, whatever was swallowed resembles pea soup. This greenish liquid is now squeezed out of the stomach into the duodenum, the top part of a 6-metre-long tube called the small intestine.

Pipes flow into the duodenum bringing a variety of other substances for breaking down further what remains of the food. Among these substances are bile – a digestive cocktail of thick, bitter, yellow or greenish fluid brewed in the liver. Although over 95 per cent water, it contains a wide range of chemicals including bile salts, mineral salts, cholesterol and bile pigments. The bile salts play a vital part in breaking down fat so the digestive chemicals (enzymes) can then go to work. Other chemicals, produced in the pancreas, neutralize stomach acid and prepare the food for absorption – its passage into the bloodstream.

Muscular contractions propel the food remains down the small intestine into regions where thousands of finger-like extensions stick out from the walls. These so-called villi contain a fine network of tiny blood vessels just below their surface. Cells on their surface absorb the useful parts of the digested food – the nutrients – and pass them into the blood.


Gaillard/Jerrican

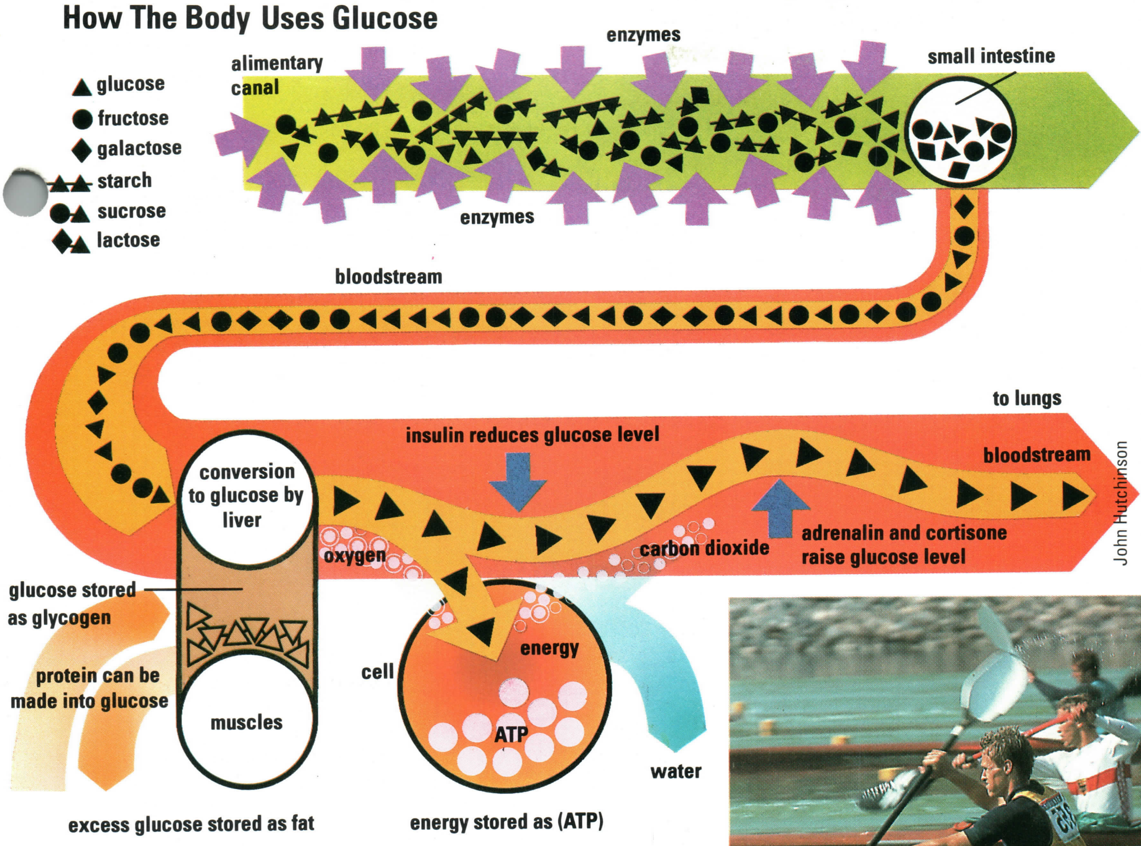
The residue *of a hamburger will end up in the large intestine (bottom right) after most of the nutrients (protein, starch etc.) have been chemically processed and absorbed in the small intestine.*


CNRI/SPL

KILOCALORIES (PER 100 GRAMS)

apple	35	cod, fried in batter	199
bacon (streaky)	424	cream, single	212
banana	47	eggs, boiled	144
beans, french	7	ice cream	167
beef (minced)	229	milk, whole, 1 pint (568 ml)	371
beef, grilled steak	218	milk, skimmed, 1 pint (568 ml)	188
bread, white	232	oranges	26
bread, wholemeal	216	potatoes, baked	85
butter	740	potatoes, chips	253
carrots	19	rice, boiled	361
cheese, cheddar	406	spaghetti	378
cheese, cottage	96	tomatoes	14
chicken, roasted	148	wine	67

How The Body Uses Glucose



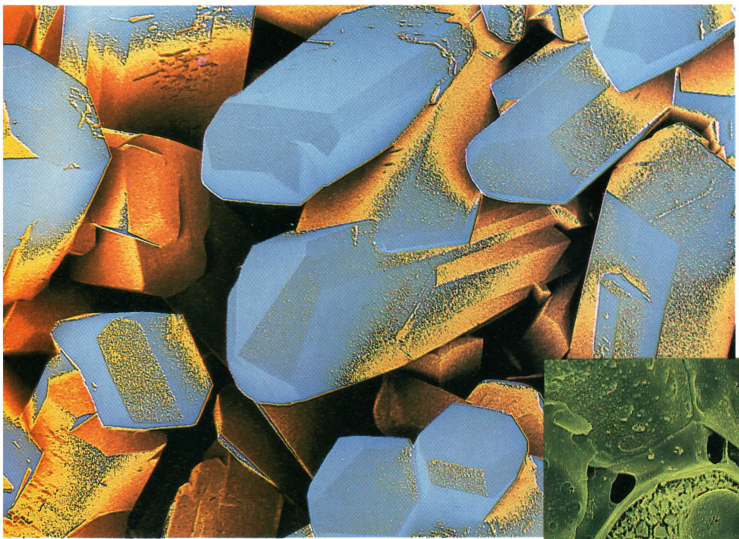
John Hutchinson

***Fuel for muscles** to operate (below) is derived from the breakdown of carbohydrates by enzymes to glucose. Once glucose is released into the blood it is taken up by the cells. Inside the cells it is oxidized to produce energy. The cells store this energy by creating high-energy phosphate compounds (ATP – adenosine triphosphate), which act like a battery to be used and recharged.*

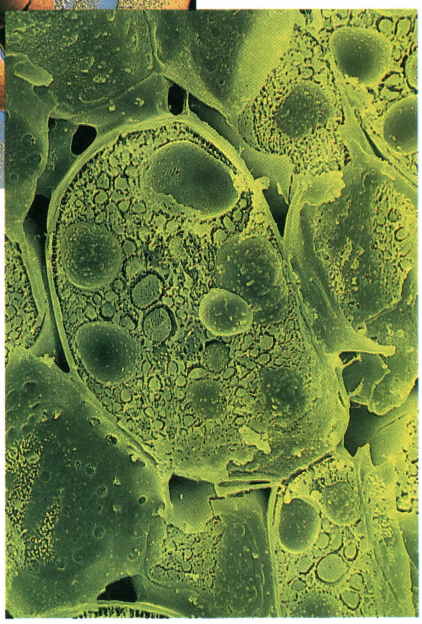
Simon Bruty/Allsport

Meanwhile, what is left-over in the small intestine continues its journey into a wider, 1.5-metre-long-tube known as the large intestine. This serves to extract most of the remaining water from the food remnants and to produce vitamins through the action of bacteria. Finally, the indigestible waste enters the last part of the large intestine ready to be forced out as faeces by the muscular walls of the rectum at the end. Ten to fifty per cent of faeces is dead bacteria, while the rest is mainly water.

***Vitamin C** – ascorbic acid – is essential for the formation of connective tissue and the regulation of tissue respiration.*



Jeremy Burgess/SPL



Dr Jeremy Burgess/SPL

***Starch grains** shown in the cells of a mature Jack bean by a false-colour electron micrograph. Starch is converted during the digestive process into simple sugars that can be utilized when needed or stored by the body as fuel.*

Once in the bloodstream, most of the tiny particles of nutrients go straight to the liver along a blood vessel that is the only one in the body that does not start or end at the heart. The liver, as well as being involved in a variety of other jobs, acts as a chemical processing plant for nutrients. Some nutrients it passes on unchanged into the rest of the blood system, others it changes into more useful substances before sending them on or storing them.

The blood system carries the final products of digestion to every cell in the body where the nutrients are put to use. Together with oxygen from the air we breathe, these nutrients are the means by which cells function, repair, and replace themselves.

Blood sugar

One way in which the food we eat is used is to operate muscles. The glucose burnt as fuel by the muscles is derived from the breakdown of carbohydrates in the intestine into small sugar molecules. These molecules are absorbed as fructose, galactose and glucose. Glucose is used directly by all cells for energy, while galactose and fructose are converted to glucose in the liver.

Any surplus of glucose in the blood is converted to glycogen and stored in the liver and the muscles until it is needed, or it is converted to fat by the liver and stored in adipose tissue. The percentage of glucose constant in the blood is 0.1. When the level drops the reserves are drawn on. The pancreas regulates the blood

sugar level by secreting insulin.

Using refined sugar as a source of instant energy, apart from the risks of tooth decay and obesity, has the drawbacks that sugar is empty of nutrients and can overstimulate the pancreas. It has also been suggested that a high sugar intake increases the risk of diabetes mellitus.

Muscles work by contracting, that is by getting shorter and thicker. In most cases, both ends of a muscle are joined to a bone, so that when the muscle contracts the bones move. Since a muscle cannot make itself longer again, a second muscle is needed that works in the opposite direction. So, muscles normally occur in pairs. For instance, the biceps muscle bends the arm, while the triceps muscle, at the back of the upper arm, straightens it again.

To shorten, muscles need a great deal of energy. This is brought to them in the blood, mostly in the form of sugars like glucose. When the glucose reacts with oxygen, also carried by the blood, it releases chemical energy, waste substances such as carbon dioxide, and heat. If many muscles are used at once for a considerable period, as in playing football or chopping wood, heat builds up faster than the body can easily get rid of and we start to sweat.

Dr Arthur Lesk/SPL

Alcohol dehydrogenase *– an oxidising enzyme – represented by a computer graphics model. Hundreds of different enzymes exist and they are involved in almost every chemical reaction in the body, acting as biochemical catalysts.*

Involuntary movement

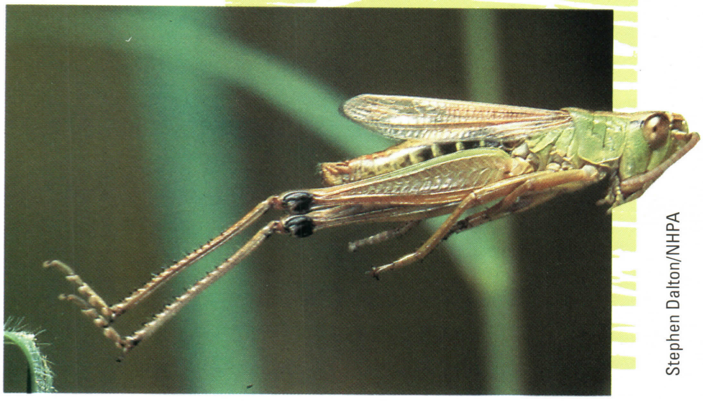
Every part of the body has its own set of muscles and, together, all the muscles make up over half the body weight. They range in size from the large muscles in the arm and leg to tiny muscles that control the face and tongue. The bulkiest muscle of the 639 in the human body is the gluteus maximus, or buttock muscle, which extends to the thigh. This contrasts with the stapedius, which controls the stapes – a tiny bone in the middle ear – which is just 1.3 mm long.

Some muscles are voluntary: which means that you choose when to use them. Many others are involuntary. Sets of involuntary muscles, for example, focus the lens in the eye or push food through the intestines.

The most important involuntary muscles of all are those which make up the wall of the heart – one of the most vital organs for the maintenance of life. The human heart weighs over 340 gm and over a 75-year lifespan it beats about two billion times and pumps around 150 million litres of blood. The average resting heart rate of an adult is between 60 and 70 times a minute. This compares with an elephant's heart which beats 30 times a minute and a shrew's which beats 800 times a minute – or more than 10 times a second.

HOPPING MAD

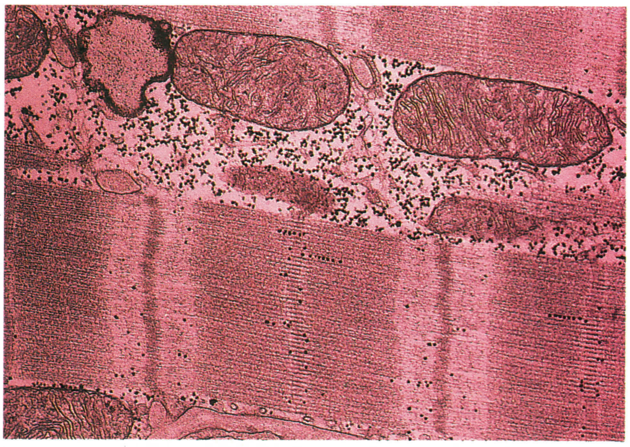
Before a grasshopper jumps, it tightly flexes its greatly enlarged back legs. This engages a small catch that effectively locks the leg in position. Then the big muscles inside the leg slowly contract, storing up energy in the same way as a piece of elastic. The muscle contraction itself takes about half a second, while the final leg movement which propels the jump is over in less than three-hundredths of a second. As a result, the elastic energy is released more than ten times faster than it was stored – producing a sudden burst of power.



Stephen Dalton/NHPA

Muscle movement, and almost every other action of the body, is controlled from the brain. Involuntary muscles, for example, are co-ordinated by a region of the brain called the cerebellum. A different region, the motor cortex, is reponsible for those movements that are under our conscious control.

As well as handling movement, the brain deals with sensations, switches on and off the production of various chemicals throughout the body, and, not least, thinks. So, it is not surprising that the brain must be well supplied with energy. Though it weighs only about 1.5 kilograms – one fiftieth of the body's weight – it uses up one fifth of the body's energy supply.



A cardiac muscle cell, *shown by means of a false colour scanning electron micrograph. The small black dots are granules of glycogen. The mitochondria (the elliptical structures along the top) are where glycogen is chemically broken down to yield energy to power muscle contraction.*

Don Fawcett/SPL

Just amazing!

GASTRIC DEUCE

THE HIGHLY-FOLDED INNER LINING OF A HUMAN SMALL INTESTINE HAS AN ESTIMATED AREA OF 250 SQUARE METRES – LARGER THAN A DOUBLES TENNIS COURT.

Paul Raymonde

THE GREEN MACHINE

Dr Jeremy Burgess/SPL

John Innes Foundation

***A turnip leaf** section, magnified 57 times by means of an electron microscope (right), showing the layers of tightly packed palisade cells in which photosynthesis takes place.*

PLANTS HAVE THE AMAZING ability to trap energy from the Sun for use in building the complex chemicals in their cells. This process, known as photosynthesis, is vital to all animals as well, since plants form the basis of the world's food chain and produce the oxygen we need to breathe.

Because most plants do not eat other living things that would provide a source of ready-made food, they must build all the complex chemicals they need from simple substances – carbon dioxide, water and minerals from the soil. Sunlight is the key which makes this possible – photosynthesis literally means 'building from light'.

The energy in sunlight is absorbed by a bright green substance called chlorophyll, which is concentrated mainly in the leaves, inside microscopic objects known as chloroplasts. Carbon dioxide from the air enters through tiny pores, or stomata. In most plants, the stomata are found on the under-surfaces of the leaves.

Water is absorbed from the soil by the roots. It then travels along the roots, up the stem, and into the leaves through narrow tubes called xylem vessels. In the leaves, xylem vessels branch out from the mid-rib as a fine network of veins.

Solar power

Photons (particles of light) are trapped by molecules of chlorophyll contained in neatly folded membranes inside the chloroplasts. The biggest concentration of chloroplasts is in the so-called palisade layer of cells, just below the waterproof upper layer of the leaf. Each photon that is caught raises the energy level of a chlorophyll molecule. This extra energy is then passed on, via a chain of reactions, to a spongy layer of cells beneath the palisade layer. The energy is carried in relays by tiny, electrically charged particles called electrons.

Carbon dioxide entering through the stomata and water arriving by the xylem vessels also collect in the spongy layer of cells within the leaf. The energetic electrons set free with the help of sunlight react with the carbon dioxide and water to give simple sugars, such as glucose, and oxygen.

These sugars pass out of the leaves through a second set of tubes running parallel to the xylem vessels. These food-carrying pipelines, or phloem tubes, transport sugars to all parts of the plant.

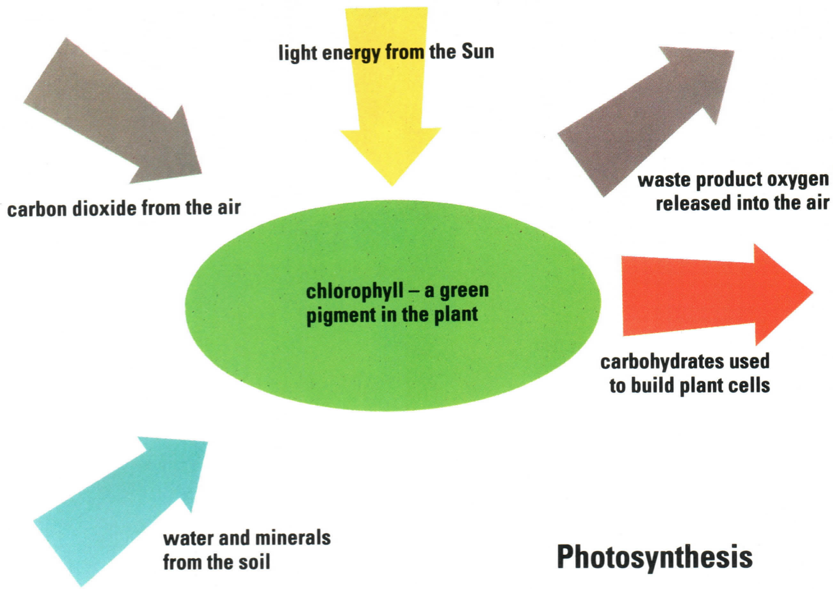
Body building

Just as steel is a raw material from which cars, refrigerators and many other finished goods are made, these sugars are a basic building stuff for making the living cells of leaves, stems, roots, flowers, fruits and seeds. A plant, however, cannot live on sugar alone. It has to assemble a wide variety of complicated substances – proteins, more complex carbohydrates (including cellulose) and fats – from sugar and from minerals extracted from the soil by its roots.

In the future, scientists hope to be able to mimic the way photosynthesis works in plants to supply some of the world's energy needs. The goal is to develop an artificial molecule with similar properties to those of chlorophyll. But whereas in plants, the end product of photosynthesis is a sugar such as glucose, in this new, artificial form it would be hydrogen – a fuel that could partly replace coal, oil and natural gas within the next century.

A molecule that does a similar job to chlorophyll has been synthesized by a team of British, French and American researchers. The middle section of this molecule can absorb a photon of sunlight and, in the process, produce an energetic electron. Normally, such an electron would immediately re-emit a photon, or series of photons, and so lose its energy again. But attached to either end of this new molecule are groups of atoms that prevent this happening. One group quickly snatches the energized electron away. Meanwhile, on the other side, a second group supplies a fresh electron to plug the hole left behind.

A different approach is to extract the light-harvesting part of a living plant – the chloroplast membranes – and then adapt these to serve human needs. Researchers are looking for a way of splitting water molecules into oxygen and hydrogen, using energy from the Sun. The hydrogen could then be stored and used as a fuel for homes, industry and transport.



Photosynthesis

Mark Franklin

__Chlorophylls__ convert solar energy into chemical energy. This changes carbon dioxide and water into oxygen and simple forms of carbohydrates called sugars.

Tony Hardwell/Hutchison Library

__When sugar-cane__ is burnt to remove the outer leaves before harvesting, energy stored in sucrose form is released as heat energy.

COAL – A FOSSIL FUEL

The solar energy trapped by plants over 300 million years ago, before the age of the dinosaurs, is released today, to warm homes and generate electricity in power stations, when coal is burned. Tall, fern-like plants (below) that grew in swamps during the Carboniferous period used photosynthesis to grow just as modern plants do. After they died, they were buried beneath an increasingly thick layer of mud and peat, until they were crushed into hard, black coal.

D Boyd/GSF

Just amazing!

PLANT POWER

THE FASTEST GROWING PLANT IN THE WORLD IS BAMBOO. SO ENERGETIC ARE SOME SPECIES THAT THEY CAN GROW UP TO 41 CM A DAY.

Paul Raymonde

Dr Jeremy Burgess/SPL

__A chloroplast__ in a leaf cell of a garden pea, magnified 1,000 times. In its centre is a starch granule. The strands running through the chloroplast contain chlorophyll pigments that play a vital role in photosynthesis.

STAYING ALIVE

- EVOLUTION
- KEEPING WARM
- CRYPTOBIOSIS

The brown rat is such a successful survivor because it will eat almost anything, animal or vegetable.

Jane Burton/Bruce Coleman Ltd

The black swallower fish, *in the ocean depths, has developed sharp teeth and extra-strong jaws that enable it to grab prey sometimes larger than itself.*

Peter David/Planet Earth Pictures

FROM FROZEN ARCTIC wastes to parched, sun-scorched deserts, many living things manage to survive in the most hostile of environments. Some strange creatures even inhabit the deepest parts of the ocean and streams of superheated water rising from undersea vents.

How does a species develop special characteristics enabling it to

survive its surroundings? Within any group of animals and plants, some individuals are better equipped to survive than others. They may be faster, more able to withstand extreme heat or cold, better camouflaged, or have some other advantage over their neighbours. So these individuals are more likely to live long enough to have offspring, some of who will inherit their parents' survival characteristics and pass them on. In this way, a new species gradually evolves that is specially adapted to its environment.

Terrors of the deep

Hundreds of species of fish – large and small – live in the warm, upper layers of the ocean, feeding on each other or on the microscopic plants and animals that thrive in sunlit waters. But below 1,000 metres, in the pitch-black cold, the struggle to survive is intense. Few fish live here, and those that do are often fierce and ugly. At a depth of 2,000 metres, the pressure is equal to the weight of two average men standing on each square centimetre. Yet for creatures living deep in the ocean the big problem is shortage of food.

Weird creatures

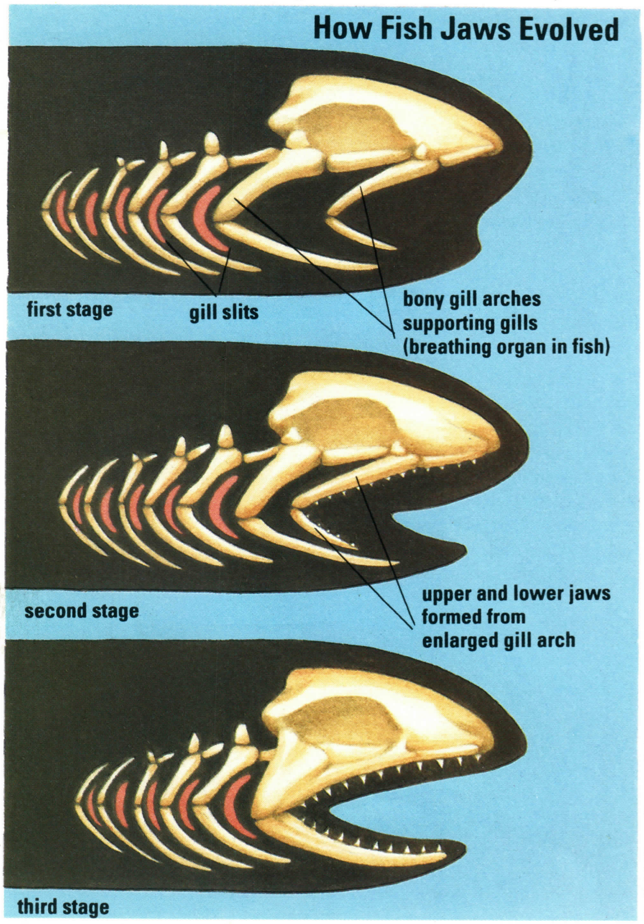
There is the gulper eel that lures its prey with a reddish light at the end of its tail and then swallows its victim whole through gaping jaws. There is the bizarre chiasmodon, whose belly is so elastic it can stretch to contain fish far larger than itself. And, most vicious-looking of all, there is the viper fish, with its long jaws of needle-sharp teeth that can snap shut like a steel trap. Yet, despite their frightening appearance, these and other deep-sea fish are actually quite small – between about 10 and 50 cm in length. Bigger fish would simply not find enough to

Frieder Sauer/Bruce Coleman Ltd

__Rotifers and tardigrades__ (left and below) are both microscopic animals that live in coastal waters, ditches, lakes and clumps of moss. They can survive long periods of drought – even decades – by drying out, until revived by a drop of water. As it dries, the tardigrade's body (below magnified 200 times) contracts into a barrel shape.

Robert Schuster/SP

__Jawless fish used__ their weak, circular mouths to suck in particles of food. With jaws, fish can catch and eat much larger prey.



Mark Iley

__Mud-skippers,__ in the tropics, comb the mud looking for insects to eat. They lever themselves forward over the mud with strong pectoral fins.

D & M Plage/Bruce Coleman Ltd

Adaptations to Arctic Ice and Snow

Mark Iley

***An Arctic hare's small ears** keep the amount of heat escaping through the skin to a minimum. Spreading feet give greater stability when walking on ice.*

eat at these depths.

At the very bottom of the ocean, below 6,000 metres, food is even scarcer. But the animals that live here have adapted to make the most of what falls down from above. A sea urchin, for instance, seems to relish a pile of dung. Other bottom feeders, like the sea cucumber, eat the organically rich sediment of the ocean floor. Still others scavenge for the dead remains of bigger animals that have drifted down to the ocean floor.

Living in the desert

In the desert, one of the biggest problems is the lack of water. Animals have evolved ways of saving as much water as possible. Insects and reptiles have body coverings that are almost impermeable. The exoskeleton of insects, made of chitin, is covered by a thin, waxy, waterproof outer layer called the epicuticle. A reptile's skin is thick and scaly, without sweat glands.

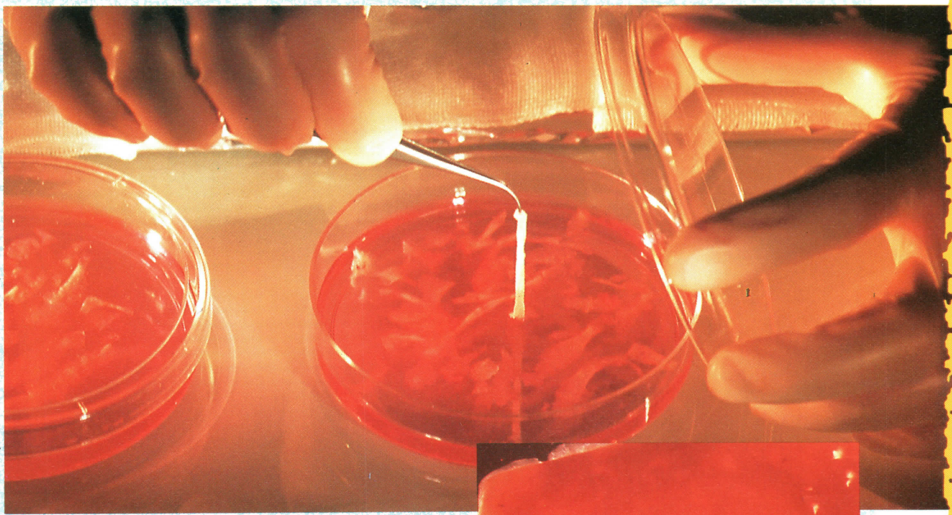
For warm-blooded animals the problem is more severe. When they are too hot, they must let water evaporate from their skin, by panting or sweating. To compensate, desert-living mammals have specially efficient kidneys that excrete as little water as possible. Many burrow into the sand

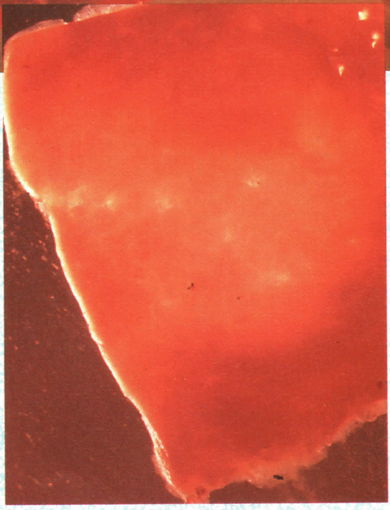
HOW TO REGROW LOST BODY PARTS

Death would come quickly to some animals unless they could replace lost body parts. As a result, these creatures have evolved so they can regenerate missing structures. A crab will regenerate (regrow) a leg or pincer that has been broken off. This is possible because the remaining cells retain a genetic 'memory' or blueprint for building a copy of the missing limb. The larvae of some amphibians can go further. They have the ability to regenerate limbs, tails, jaws and parts of the brain.

Most mammals cannot regrow missing parts – they are more specialized in the healing of wounds. Oddly enough, healing can work against regeneration. New skin and even bandages are believed to hinder the regrowth of severed finger tips in young children.

P Plailly/Science Photo Library





P Plailly/Science Photo Library

Jane Burton/...e Coleman Ltd

However, Man can now 'grow' artificial skin from a tiny piece of real skin. First, the dermis and epidermis are separated (above) and then cells from the epidermis are 'sown' on to a fragment of dermis. This will develop into a larger section of reconstituted skin.

R Carr/Bruce Coleman Ltd

***The grey tree frog of North** America is well adapted to life in the trees, with suction pads on the ends of its fingers and toes.*

to escape the extreme temperatures of the surface. The kangeroo rat of American deserts conserves water so efficiently that it does not need to drink at all – it can survive on a diet of seeds and insects.

Death in life

Human beings die if they lose as little as a fifth of the water in their bodies. But so-called cryptobiotic animals can give up 99 per cent of their body water and still survive. Their metabolic rate is reduced to a level that is almost undetectable.

One such creature is the tardigrade. Less than 1 mm long, it lives in pools or films of water that may dry out. When this happens, the tardigrade shrivels up, showing almost no signs of life. In this state it is incredibly tough. Dehydrated tardigrades have survived temperatures of 151°C for 15 minutes and 1,000 times the quantity of X-rays that would kill a man.

In one case, tardigrades came to life after a dry chunk of moss was rewetted. The moss had spent the previous 120 years in a museum! By remaining in cryptobiosis for long periods, it seems, tardigrades, rotifers and other such creatures can extend their lifespans up to 100 times.

In another instance, a dry tardigrade emerged alive from a scanning electron microscope in which the pressure was as low as a millionth of a millimetre of mercury. Given such powers, it may even be that some cryptobiotic animals and plants could survive the cold, radiation-blasted vacuum of outer Space.

Certain insects and fish that live in polar regions have another incredible survival technique. They produce chemicals, such as glycerol, that lower the freezing point of their body fluids – a kind of natural antifreeze.

Other animals, including some species of frog, can actually survive being frozen. The grey tree frog, the spring peeper and the wood frog all hibernate in areas where the winter temperature may fall as low as −10°C. When this happens, over one third of the frog's body fluids freeze solid. In spring, as the temperature rises, the frog gradually revives and continues life as normal.

Bear necessities

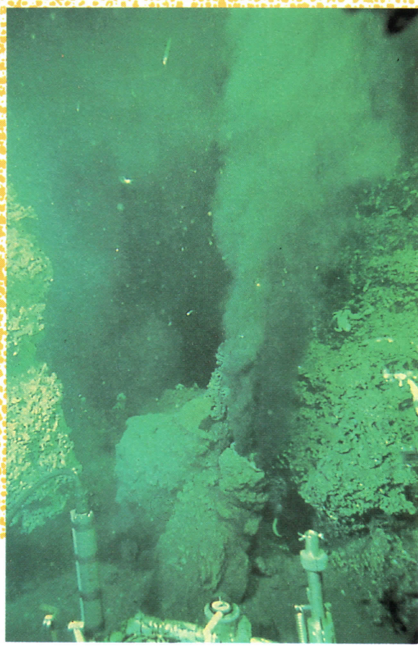
Polar bears have their own special adaptations for living on polar ice. A thick layer of fat insulates them from the cold, while huge, rough pads on their feet give them excellent grip. Their fur is a very effective insulator. The outer hairs stand erect like a brush over the dense underfur. Snow does not melt on the outer hairs, although the skin feels warm to the touch. Much of the visible and infrared light from the sun passes through the outer hairs and is absorbed by the skin and a thick layer of air trapped around the woolly underfur.

OUT OF THE FIRE

Nearly half of the 900,000 hectares of forest in America's Yellowstone National Park was scorched by fires in 1988. Yet almost immediately the richly varied plant and animal life in the park began to recover. Lodgepole pines – the most common tree in Yellowstone – produce two kinds of seed-bearing cones. Some (below) open as soon as they mature. Others can survive the flames of a forest fire and, indeed, will only open after they have been heated, ensuring new growth even when a whole section of forest has burned down.

A-Z Botanical Collection

MICROBES – THE HARDIEST SURVIVORS



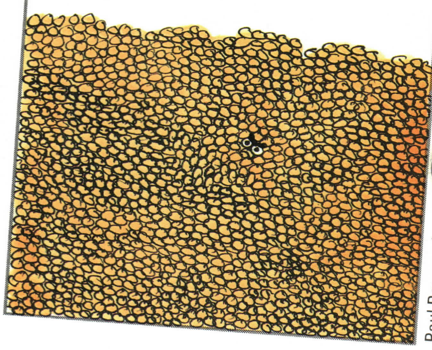
P Ryan/Scripps/SPL

Some of the smallest living things on Earth are also the toughest. Nearly 2,000-year-old spores of bacteria, for example, have been taken from the Roman fort of Vindolanda, close to Hadrian's Wall, and germinated in the laboratory. Another species of bacteria was discovered in 1982 living in the superheated water spewing from under sea vents known as a 'black smokers'. Water from such a vent (left) has a temperature of up to 300°C – hot enough to destroy the proteins and other complex molecules found in living cells. Yet the new strain of microbe thrived at such temperatures and would die if 'cooled' to 100°C – the normal boiling point of water. Bacteria have also been found floating high in the atmosphere and, in soil, as deep as 8 metres.

Just amazing!

MULTIPLE BIRTH

SURVIVAL FOR SOME SPECIES INVOLVES PRODUCING FANTASTIC NUMBERS OF OFFSPRING. IN ONE SPAWNING, FOR EXAMPLE, AN OCEAN SUNFISH MAY LAY 300 MILLION EGGS.



Paul Raymonde

SOME LIKE IT HOT

AFTER TEN PARCHING DAYS crossing the desert a camel pauses for its first drink of water and takes in nearly 100 litres before finally satisfying its thirst. This capacity of the camel to go without a drink for such a long time is just one of the many solutions found in nature to deal with the harsh conditions of arid lands.

Lack of water, intense heat during the day and cold by night are the challenges to life in the desert, and there are as many solutions to these challenges as there are living organisms surviving in this arid environment.

In the Namib Desert of South West Africa, there are areas where the rainfall is almost non-existent. But amazingly, life is present. Many plants and creatures do not get their water from the ground but collect moisture from the air. Close to the coast the annual average rainfall is only about 15mm a year. However, fog from the Atlantic Ocean does roll into the desert for 80 km, for about 60 days every year. This fog is caused by water condensation as warm, moist air passes over cold waters near the coast.

One plant, the *Arthaerua leubnitziae*, grows only in the coastal fog belt. On the desert surface the plant usually shows only green stems (leaves only appear briefly after the infrequent rain). These stems have deep grooves that radiate from the centre to look like a wheel's spokes. This arrangement reduces evaporation but scientists believe that the plant has very unusual ways of getting water from the air. In one of these, salt crystals on the surface of the stems are thought to extract moisture from the fog.

***The Anchieta's dune lizard** uses its duck-like snout and long toes to delve into the Namib desert dunes in search of cooler sand.*

Rod Williams/Bruce Coleman Ltd

***The blotched blue-tongued skink**, a native of the Australian desert, has small, broad limbs to help it move through the sand.*

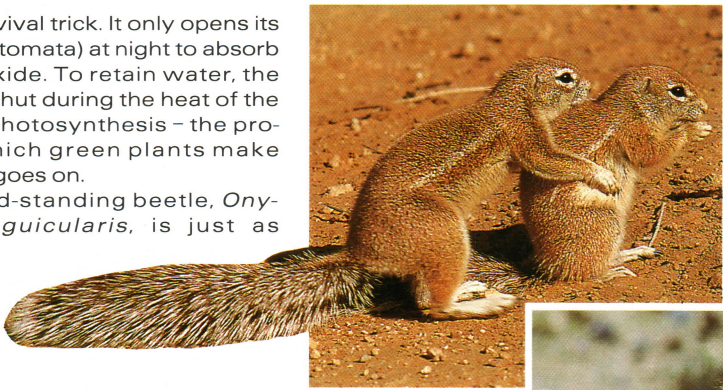
Anthony Bannister/NHPA

Fog drinker

Another fog drinker is the *Welwitschia mirabilis*, a plant that can live for over 1,000 years. It grows just two leaves that live for the entire time the plant is alive and these leaves can give a surface area of over 20 square metres capable of absorbing moisture. In the extreme parts of the Namib, the *Welwitschia* has

Carol Hughes/Bruce Coleman Ltd

***The head-standing beetle** waits upside down to collect waterdrops that have condensed on its body during the Namib desert night.*



Barrie Wilkins/Bruce Coleman Ltd

***The ground squirrel's** bushy tail can be flexed over its head like a parasol when the Sun beats down on the desert.*

another survival trick. It only opens its leaf pores (stomata) at night to absorb carbon dioxide. To retain water, the pores stay shut during the heat of the day while photosynthesis – the process by which green plants make their food – goes on.

The head-standing beetle, *Onymacris unguicularis*, is just as ingenious. When it is foggy, it climbs up to the top of dunes and tilts its head and body down while facing into the wind and stretching out its rear legs. Water droplets from the fog collect on its body and run down into its mouth. Other beetle species – *Lepidochora discoidalis, L. kahani* and *L. porti* – dig trenches up to 1 metre long that collect moisture as the fog blows over them. The beetles come back later and extract the water in the ridges of sand created while digging their trenches.

Body heat

Virtually every creature living in the desert has evolved in some way to cope with the conditions. The range of adaptations goes from the large ears of the bat-eared fox, which not only help with hearing but also radiate heat away, to the sabre-horned gemsbok, *Oryx Gazella*, which can survive all day in the heat with a body temperature raised to 45°C - 6°C above its normal. The gemsbok can only do this by having a special heat exchanger at the base of its brain. This cools the hot blood pumped up from the animal's heart towards its head by exchanging heat with cooler blood in veins around its nose where breathing cools the tissues. This way its brain is kept cool enough so no damage is caused.

Carol Hughes/Bruce Coleman Ltd

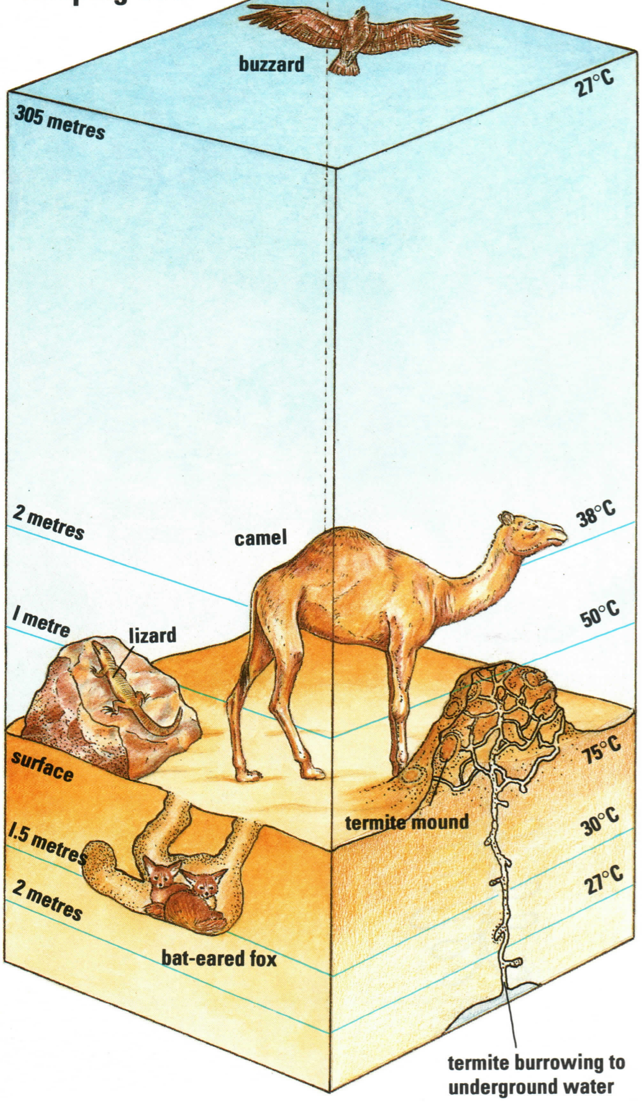
***The large ears** of the bat-eared fox help it locate prey and provide a large surface through which heat can be lost, keeping the animal cool.*

Desert dancers

Dancing and running can, believe it or not, also reduce body temperature. The *Aporosaura anchietae* lizard lifts two feet off the desert at once (left front and rear right) then alternates in an effort that looks close to dancing to keep its temperature down. A beetle, the *Onymacris plana*, runs across the burning sand fast enough to reduce its temperature by 10°C. In contrast, the Kalahari ground squirrel shades under its tail which it lifts over its head and body like an umbrella.

Camels, contrary to popular belief, do not carry excess water around in their stomach or humps. They do, however, store water in the fat in their

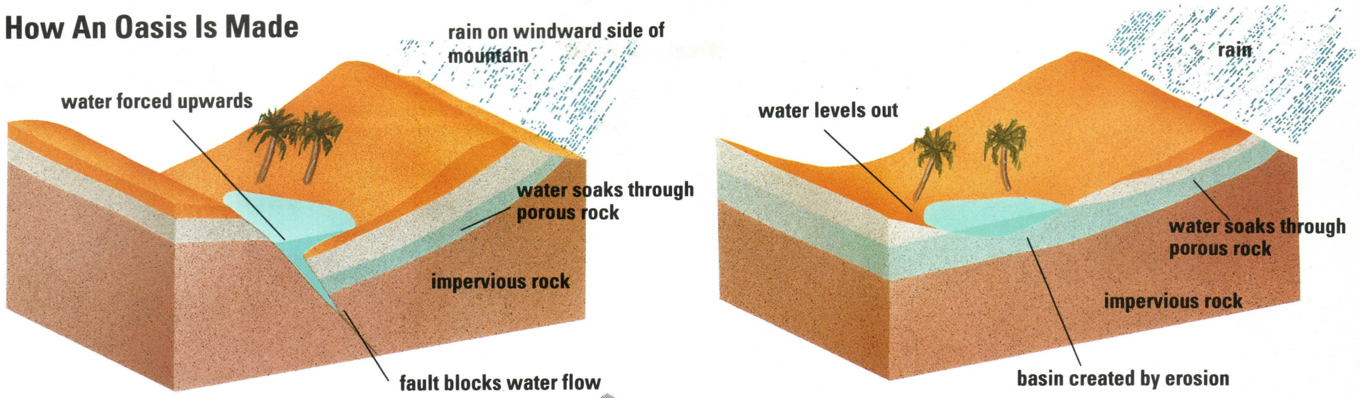
Keeping Cool



Paula Knock

***Animals** use a wide array of strategies to keep cool in the desert. The bat-eared fox digs a den nearly two metres underground and termites burrow deeper still in search of water. The buzzard glides on air, 300 metres up, which reaches only 27°C. Even the lizard finds some relief a metre above ground level.*

How An Oasis Is Made



Mark Franklin

To form an oasis, *rain soaks through a sloping layer of porous rock until it reaches impervious rock and is forced upwards (left) or fills a depression (right).*

MONKEYING ABOUT

Baboons living in a canyon of the Namib desert in South West Africa have modified their activities to reduce the problems caused by the extreme temperatures and the lack of water. Unlike other baboon populations which drink every day, they can sustain themselves without water for up to a month, seeking out moist plants and tree bark to satisfy their thirst. They take it easy in the heat and the young baboons do not play. To seek refuge from the heat, before lying stomach down in the sand, they dig away the top, hot layer to reach the cooler layers beneath. Whenever possible, they rest in the shade – and the males of the group do not even bother to chase the females!

bodies, and the hump is mostly fat. The average camel hump weighs about 40kg. As fat is used up to provide energy it also releases water, and a kilo of fat provides almost a litre of water. Thus a 40kg hump can provide 40 litres of water. From the fat in the hump and from other parts of its body, a camel can lose up to 33 per cent of its weight when it goes for extended periods without water.

Spectacular water storers in the plant world are the cacti, native to arid lands in the New World. The deserts of South America, the American Southwest, and Mexico have high summer temperatures, bright sun, and droughts followed by short periods of heavy rain. During the drought the cacti draw on the reserve of water in their stems. When it rains they top up their stores.

Survivors

Cacti have several other adaptations to help them survive. While most plants lose water through their leaf pores, most cacti do not have leaves or if they do, very few. Their green stems take over the food-making job that the leaves normally perform. Also, cacti stems are shaped to minimize water loss. Most are roundish, and several form tall, thick columns. The stem surface is frequently divided into sections by ribs running from top to bottom of the plant. These allow the cactus to swell and shrink with water gain and loss – like the bellows of an accordion.

Succulents

Most cacti are members of a group of plants called succulents that store their water in plump, fleshy leaves or stems. The South African Purslane or Elephant Bush plant, *Portulacaria afra*, stores moisture in its leaves. It comes from the dry areas of South Africa where it is also known as Spekboom which means 'bottle tree'.


J & D Bartlett/Bruce Coleman Ltd


J Foote/Bruce Coleman Ltd

The Gila woodpecker *pecks out a nest in a Saguaro cactus. The plant (left), a native of the Sonoran desert in Arizona, USA, can reach 15 metres in height and store up to a ton of water.*

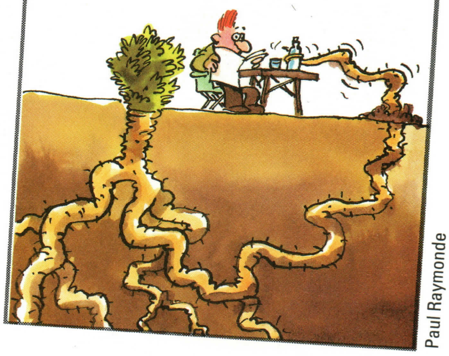
Welwitschia mirabilis *draws moisture from the fog through a single pair of leaves, which grow to a surface of 20 square metres.*


Dr Eckart Pott/Bruce Coleman Ltd

Just amazing!

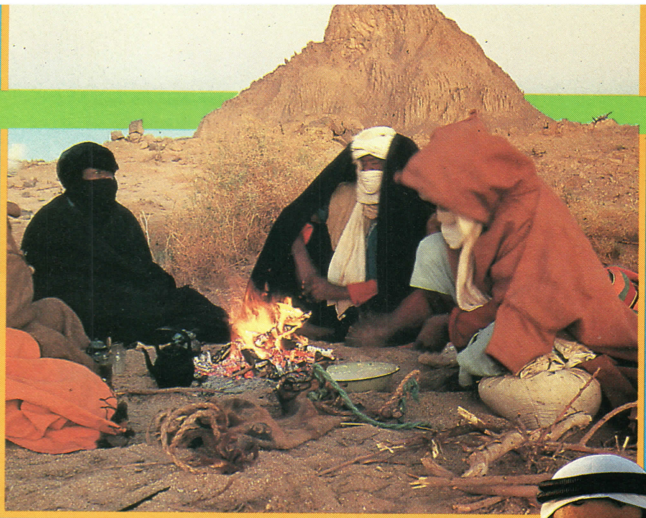
DEEP ROOTS

IN THEIR SEARCH FOR WATER THE ROOTS OF THE MESQUITE BUSH CAN GROW 53 METRES – NEARLY AS DEEP AS LONDON'S DEEPEST UNDERGROUND STATION.


Paul Raymonde

B & C Alexander

Blocks of snow slotted together to form an igloo give effective insulation against wind and cold in the inhospitable Arctic.

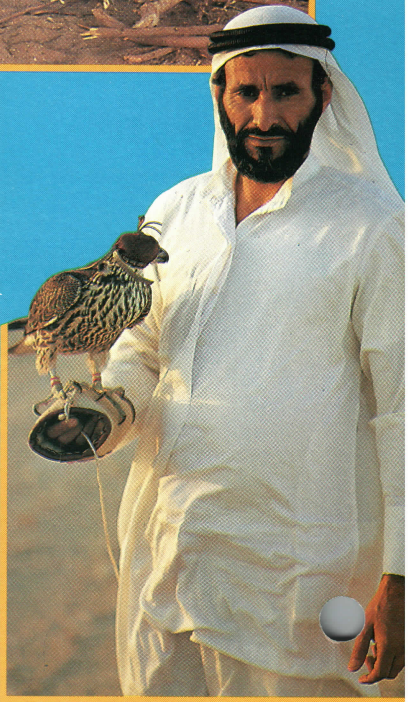


/Jerrican

Nomadic Tuaregs wear face veils and loose robes as a shield against the sand and sun of the Algerian desert.

S Patrick/Sipa/Rex Features

The arid Tenere plain in the Niger desert is the daunting setting for a motorbike race.



B Gerard/Hutchison Library

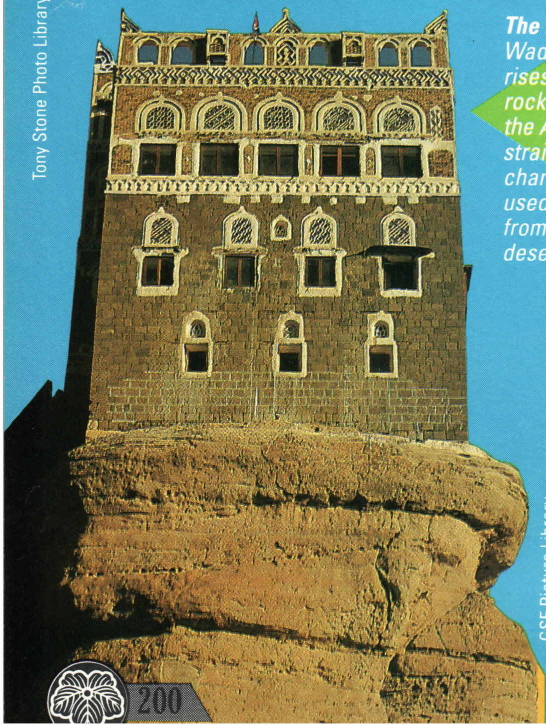
Falconry is a popular sport in many of the desert countries of the Middle East. The trainer keeps the bird unflustered by fitting a hood over its head.

Jerrican

Precious water is measured out in drops in the Abu Dhabi desert: perforated pipes take a trickle of water to each valuable plant.

Tony Stone Photo Library, London

Las Vegas, the largest city in Nevada, is a man-made oasis in the driest state of the United States.



Tony Stone Photo Library, London

The Rock Palace at Wadi Dhar in Yemen rises on a barren, rocky outcrop. Wadi is the Arabic term for straight-sided water channels, which are used to collect rain from sudden, heavy desert downpours.

GSF Picture Library

A scoop wheel draws water for irrigation in the Nile Valley. A cow yoked to a vertical shaft powers the wheel in the pit.

ANIMAL PURSUITS

Simon Bruty/Allsport

Horse-racing at Lingfield Park, UK, where the grass surface has been replaced by an American-style 'all weather' track made of crushed rock, sand and dirt.

Bo rtin/Allsport

***On the track**, a racing greyhound must wear a light muzzle, together with a coloured jacket marked with the number of its starting-trap.*

SPEED AND STAMINA ARE the qualities that make a good racing animal, together with a mind that can be trained without being broken.

The most popular racing animal is the horse. Horse-racing was included in the Greek Olympic Games, as long ago as 648 BC. Racing as we know it today, however, began in the UK. Britain's oldest major race, the St Leger, was first held at Doncaster in 1776. It is run over 1 mile and 6 furlongs (2,932 metres). British and American races are measured in miles and furlongs (there are 8 furlongs in 1 mile) while French and Australian races are expressed in metres.

Races on the flat are run between highly trained horses, whose bloodstock is traceable back over hundreds of years. In the 17th Century the fastest horses were Arabian, from the Middle East, North Africa and Turkey.

It is claimed that the blood in all 200,000 or so thoroughbreds around the world can be traced back to three Arab stallions imported into Britain in the early 18th Century: the Byerly Turk, the Godolphin Arabian and the Darley Arabian.

The thoroughbred

Breeding horses became a specialized and highly regulated business. Selective cross-breeding between the Arab and native English stock produced a hybrid known as the thoroughbred – the classic racehorse.

Thoroughbreds are not allowed to race until they are 2 years old. The official birthday of every racing horse is 1st January of the year in which it was born. So all thoroughbreds born in the same calendar year are classed

as the same age. South of the Equator, a thoroughbred's age is calculated from 1st August, because the racing season falls at a different time of year.

Record time

Some races are limited to one age group or gender. For example, the Derby is for three-year-olds only, because that is considered to be when the horses are at their fastest. The record time over the one and a half mile (2,400 metres) course is 2 minutes 33.84 seconds.

Owners will pay vast sums for thoroughbred horses, or to have their mares bred with – or 'sired' by – classic stallions at stud farms. Stud fees can reach hundreds of thousands of dollars. Annual auctions such as the Keeneland Selected Sale in Kentucky take in over $100 milion a year. Millions of dollars have been paid for promising yearlings.


Fritz Prenzel/Bruce Coleman Ltd

***The Camel Cup Race** in Alice Springs, central Australia. Racing camels is a popular sport in desert areas all over the world, especially the Middle East.*


Bob Martin/Allsport

***Harness racing** in St Moritz, Switzerland. Modern harness racing developed in the USA.*

Classic races

The St Leger is one of five 'classic' flat races run annually in England. The others are the Oaks, the 1,000 Guineas, the 2,000 Guineas and, most famous of all, the Derby. The prize for winning the Derby is over $570,000 and there is $950,000 for the Arc de Triomphe in Paris. But these sums pale in comparison to the $5,700,000 prize money for the Breeders' Cup Classic staged in the USA.

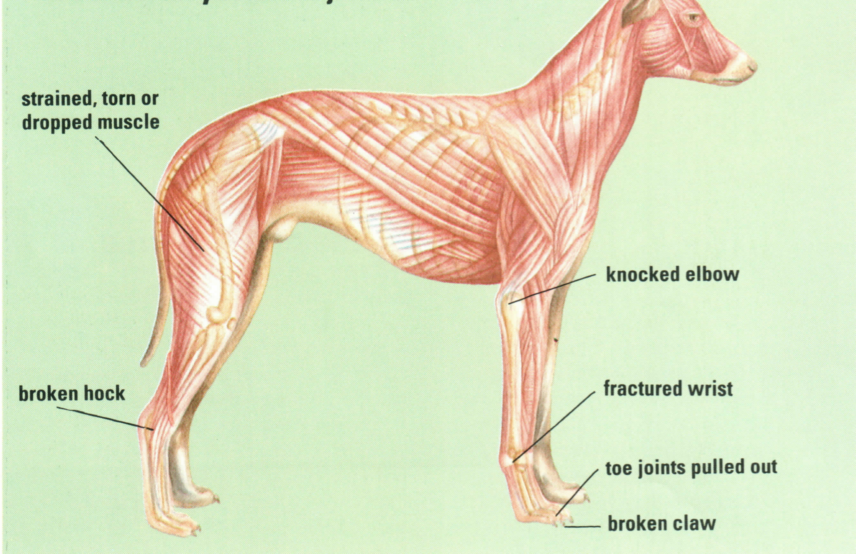
All-weather tracks

The English flat racing season is in the summer, when grass race courses are in their best condition. However, in the USA racing is on dirt tracks as well as grass and so continues, whatever the weather conditions, all year round.


Russell Cheyne/Allsport

***Greyhounds** chasing a 'hare'. The world speed record for a greyhound is an amazing 67 km/h.*

Common Greyhound Injuries



Gerald Eccles

***Muscles and bones** can suffer injury, especially at the joints, due to high-speed cornering and jostling for position.*

Some 60,000 horse-races are run in the States every year.

In winter, when the European flat racing season is over, there is National Hunt racing instead. In hurdle racing, horses run along a course at least 2 miles long, jumping at intervals over hurdles of gorse or spruce on a wooden frame. In steeplechasing, the fences are taller and the courses longer. Cross-bred between hunters and thoroughbreds, hurdlers and steeple-chasers are generally older, slower and hardier than horses that run on the flat, so they can withstand the heavier (wetter) conditions.

The most famous steeplechase in

MAN AGAINST HORSE

There is an annual hill race in the Cambrian Mountains in Wales between runners, cyclists and horses. The cross-country course is 35 km long. Some 40 horses and riders, 500 runners and 100 cyclists take part. The winners are usually cyclists, followed by the horses. There is a special prize – never yet won – for the first runner to beat a horse home. In 1982, the first athlete was just four minutes behind the last horse.

the world is the Grand National, held at Aintree in Liverpool, UK, every March. The course is four and a half miles (7,220 metres) long. The horses must jump over 30 fences before the race is over. These fences are made of thorn and spruce; some are as high as 1.5 metres and many are flanked by ditches. Because of the number of horses that have fallen during the race and been fatally injured, the worst jumps have recently been reduced in size to make them less dangerous.

One form of horse-racing, which is very popular in the USA and Australia, but less so in Europe, is harness racing. Horses draw drivers sitting in lightweight carriages. There are two types of harness racing: the original, but now less popular, trotting, and pacing. Trotting and pacing are very similar. A single horse pulls a driver in a two-wheeled 'sulky' over courses of up to two miles (3,200 metres).

Trotting and pacing

The major difference is in the horse's gait, or stride. In trotting, the horse moves the left front leg and the rear right leg forward simultaneously, whereas pacers move both legs on the same side together in what is known as a lateral gait.

Also, pacers wear hopples – straps or girdles – that hang around the legs and stop the horse from running too fast. (Hopples were first used to stop horses galloping when ridden by women.) Despite this handicap, the world record for pacing over 1 mile of 1 minute 49.2 seconds is faster than the trotting record over 1 mile (1 minute 52.2 seconds).

In the USA, harness-racing often takes place at night, in floodlit stadiums. In the UK, it is greyhounds that are raced in the evening. Dogs are raced on specially constructed dirt tracks, either in 200-metre sprints, longer marathons of 1,200 metres, or over hurdles. Greyhounds are the fastest breed of dog. (Incidentally, they are never grey-coloured. The name comes from the Icelandic *grey* – meaning dog – and *hundr* – meaning hunter.) They hunt by sight, as opposed to hounds, who hunt by scent. Therefore, they can be enticed to run at the sight of a dummy hare.

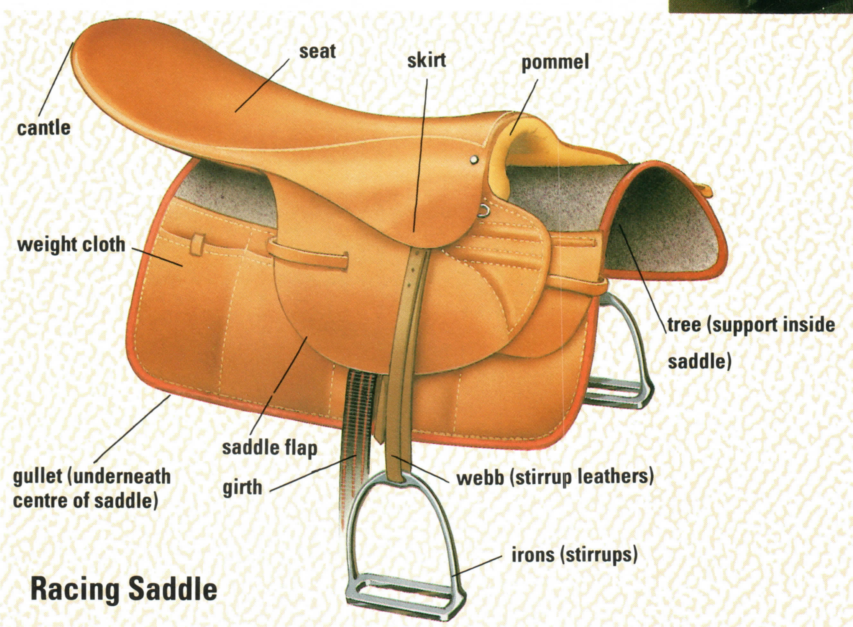
Chasing a 'hare'

The electrically operated hare is usually a skin stretched over a frame. It runs with a bobbing movement on a rail along the inside or outside of the oval-shaped track. As it passes the

D Kasterine/Telegraph Colour Library

Before a race, *every jockey must be weighed with his equipment, including the saddle. The total must match the weight assigned to his horse. It helps if the jockey himself is as light as possible.*

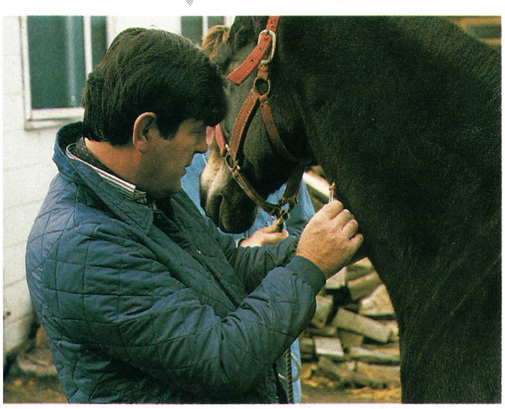
A jockey *will have at least three saddles of different weights, ranging from 2 to 9 pounds (0.9-4 kg). Which one he chooses depends on the size of the horse and the weight to be carried.*



Racing Saddle

Paul Williams

Blood samples, *both routine and random, and urine tests are performed by vets, to make sure that racehorses have not been drugged or received illegal medication.*



Only Ho icture Agency

Mike Roberts/Only Horses Picture Agency

Grain *is one of the horse's staple foods, together with grass and hay. A heavily exercised horse will eat 4-11 litres of crushed oats a day, sometimes mixed with bran, maize or chaff.*

starting traps, it triggers a mechanism that opens the front grill and releases the dogs. A controller makes sure that the hare is not so slow that it can be caught or so far ahead that the dogs lose interest. Race lengths vary, but they are all under 1 km.

Homing instinct

Pigeon racing developed from the use of homing pigeons for carrying messages. From wherever they are released, pigeons will always make for their home loft. The homing instinct has never been properly explained. Naturalists speculate that the birds are guided by the position of the Sun and have a highly developed visual memory.

Tricks of the trade

To increase a pigeon's motivation to return home as quickly as possible, pigeon trainers, or 'fanciers', will separate a cock they are about to race from his mate and then show her to him just before he is basketed. Similarly, they might race a hen who is sitting on some eggs and will be eager to get back to them.

The sport is popular in countries as far apart as the UK, Australia, Japan and the USA. In a race, the time when the pigeons are released at the starting point is carefully recorded. As soon as a contestant arrives home, the owner removes the race band from its leg and records the time by placing the ring in a special clocking device. The pigeon who has the best time over the distance is the winner.

Speed records

Champion pigeons commonly change hands for more than $57,000. In level flight and windless conditions it is not likely that a pigeon will exceed 96 km/h. However, the record is a speed of 177.14 km/h, recorded in 1965 in a race starting in London, UK, when the pigeons were helped on their way by a powerful south-south-west wind.

There are a number of more unusual animal races. Sheep, rabbits, ostriches, turkeys, hippopotamuses and water buffalo have all been raced against animals of their own kind.

In Sussex, UK, there is an annual duck race. Little restriction is placed on the number or size of entrants. The birds do not seem to be very competitively minded, as the event usually ends in chaos. This is also often the fate of other fun races, such as the Hentucky Derby in Kent, (also UK).

Toad racing, a popular sport in Queensland, Australia, is much more organized. The 'race track' is a series of concentric circles, which increase in size up to a diameter of about 2 metres. The toads are placed in the central circle and covered with an upturned bucket.

Stage fright

When the bucket is lifted away, the race begins. Some toads are so frightened by the roar of the crowd that they are unable to move. Others are encouraged by the commotion. The winner is the first toad to cross the line of the outermost circle.

THE ART OF TRAINING AND RACING SNAILS

Snails are certainly not noted for their speed, but there are a number of people who train snails for racing. Snails in training are fed a special diet of cucumber, parsley and lettuce. Eggshell and bonemeal is also eaten to keep the shell hard and in good condition.

At a snail race in Norfolk, UK, the 22 contestants were reduced to 17 when five snails were immediately disqualified for refusing to leave the starting line. The time set at the Norfolk race was 2 minutes 30 seconds over a course 33 cm long – 0.22 cm per second. In another race in Michigan, USA, the winner, Verne, completed the 31 cm course in 2 minutes 13 seconds – 0.233 cm per second. For races to be truly comparable, the sport must draw up a set of international rules. The Norfolk snails might have averaged a much quicker speed over a shorter, 31 cm course.

Rex Features Ltd

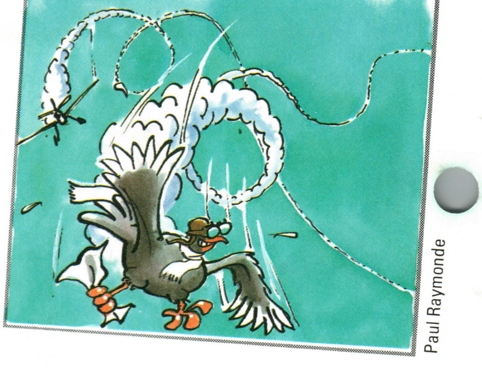
Colin Jarman/Action Plus

***Pigeons released into the air** at the start of a race begin the long journey back to their lofts. Homing pigeons have been known to fly 1,600 km and more in as little as two days.*

Just amazing!

PIGEON HEROES

THIRTY-TWO BRITISH RACING PIGEONS WERE AWARDED THE DICKIN MEDAL FOR CARRYING MESSAGES 'ABOVE AND BEYOND THE CALL OF DUTY' DURING WORLD WAR II.



Paul Raymonde

BURIED ALIVE | BODY HEAT | SUBMERSION

TO THE LIMIT

IT IS AMAZING WHAT THE human body can withstand. It is capable of being pushed to extremes of heat and cold, altitude and depth either involuntarily or because of people's desire to prove that they can do what nobody else has done before.

One of the most bizarre world records was set by 'County' Bill White of Texas, USA, who went underground on 31 July 1981 and did not emerge for 141 days. He was buried in a coffin, which had a single hole, used for feeding and breathing purposes, at a depth of more than two metres. This is the official record for a person being deliberately buried alive.

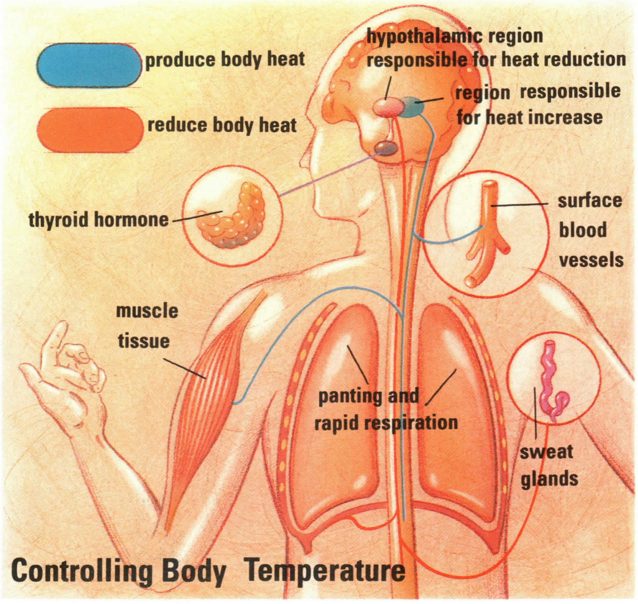
No one, however, can survive being buried without being able to breathe. The human brain can be damaged if it is starved of oxygen for longer than two minutes, so it relies on the heart to keep pumping oxygenated blood around the body. But the heart of a Norwegian fisherman once stopped after he fell into icy waters and his body temperature dropped to 24°C. When he was rescued, he was taken to hospital and connected to a heart-lung machine normally used during heart surgery and resuscitated. His heart had stopped beating for a total of four hours, but he made a full recovery. It is

Gamma/Frank Spooner Pictures

Gamma/Frank Spooner Pictures

__The Samung Lions,__ the South Korean baseball team, training for endurance in a temperature that registered –32°C.

__Marathon runners__ in the desert, wearing protective clothing against UV rays. They can lose up to ten litres of water a day as sweat. This must be replaced to avoid dehydration.

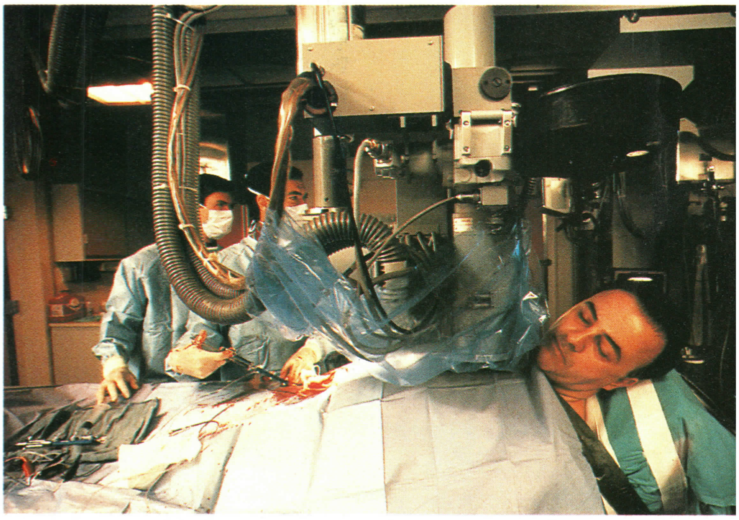


Joe Lawrence

The hypothalamus, *in the middle of the brain, ensures that the body temperature is maintained at the normal level of 37°C. It does this by relaying signals via the autonomic nervous system.*

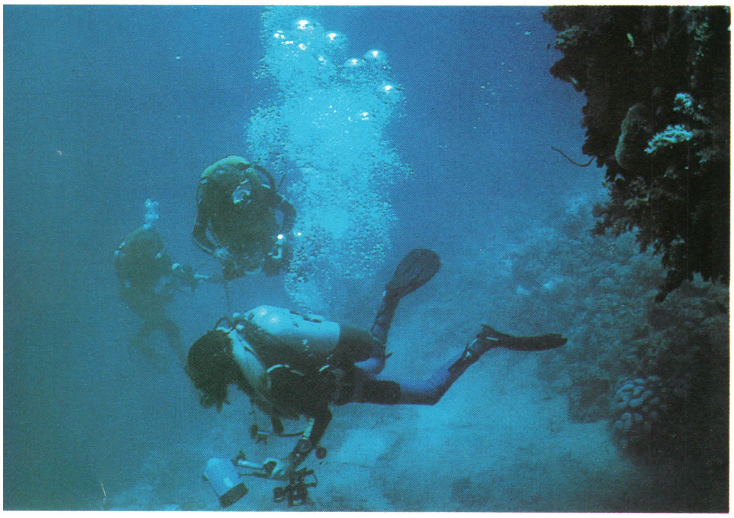
thought that the extreme cold sent his body into shock, which allowed him to survive for such a long time.

The normal temperature for a human body is around 36.9°C, and people can die of hypothermia at body temperatures of 35.0°C or lower. But in the USA there have been three recorded cases of people surviving with body temperatures as low as 16°C. Two of them were young children in freezing conditions, and the other was a 32-year-old woman whose pulse rate had dropped to an incredible 12 beats per minute, compared to the average of 80 beats per minute for a healthy woman.



Body cooling *is artificially induced during this heart surgery to lessen the metabolic rate and the oxygen requirements of the body's tissue*

Alexander Tsiaras/Science Photo Library



Increased pressure *under water can result in decompression sickness when the diver surfaces. The decreased pressure causes gas to come out of the blood at a faster rate than it can be exhaled through the lungs. The blood then fills with gas bubbles, which interrupt the blood flow and can cause death.*

Dr George Gornacz/Science Photo Library

The highest recorded body temperature was found in a 52-year-old man in Georgia, USA, who was examined in hospital after suffering from heatstroke on a hot day and found to have a temperature of 46.5°C. His temperature fell to normal within 24 days and he was discharged.

There have been tests to see what extremes of temperature the body can endure. In 1960 the US Air Force carried out experiments and found that the highest dry-air temperature that a naked man could endure was 204.4°C and for heavily clothed men, 260°C. This is two and half times hotter than the temperature at which water boils, and considerably hotter than that needed to cook a steak.

The greatest depth underwater achieved by a human was in 1960, when two scientists reached a depth of 10,917 metres in a US Navy bathyscaphe, which is a type of submarine. It is specially built to withstand the enormous water pressures at these depths – in this case 1,183 kg/square cm. The descent took four hours and 48 minutes, while the bathyscaphe rose in three hours and 17 minutes.

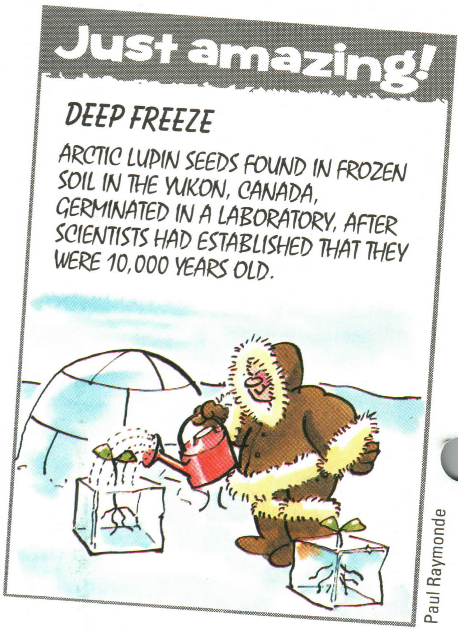
Hyperventilating

But such a depth was achieved with a special vehicle and supplies of air. The record for diving deep underwater while holding one's breath is held by Frenchman Jacques Mayol, who dived to a depth of 105 metres on a specially constructed 'sled' in 104 seconds and came back up to the surface in 90 seconds, which means he was without air for over three minutes while underwater.

Even more extreme was Californian Robert Foster who was completely submerged under three metres of water for nearly 14 minutes. He did this by hyperventilating – rapidly breathing in large amounts of oxygen so as to build up a reserve supply.

The greatest depth achieved with scuba was 133 metres by two Americans in 1968, while three men reached a depth of 685.8 metres in a diving bell, breathing a mixture of nitrogen, oxygen and helium.

There is another form of diving which pushes the human body to its limits. The land divers of Pentecost Island, New Hebrides, dive towards the ground from platforms some 30 metres high with vines attached to their ankles. Their body speeds reach about 50 km/h, which means that they experience a gravitational or g-force of more than 110 times that of the Earth's gravitational pull.



Paul Raymonde